DIGITAL SIMULATION OF BEAS SUTLEJ SYSTEM

A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

by
VIJENDRA SINGH

to the

INDIAN INSTITUTE OF TECHNOLOGY KANPUR
NOVEMBER 1978

DEDI CATED

TO

MY PARENTS

CE No. 56884.

- 9 FEB 1979

CE-1978-M-SIN-BIG

CERTIFICATE

This is to certify that the thesis "Digital Simu-lation of Beas-Sutlej System" submitted by Shri Vijendra Singh in partial fulfilment of the requirements for the degree of Master of Technology of the Indian Institute of Technology, Kanpur, is a record of bonafide research work carried out by him under my supervision and guidance. The work embodied in this thesis has not been submitted elsewhere for a degree.

Dated November ,1978

(S.Ramaseshan)

Professor

Civil Engineering Deptt.

POST GRADUATE OFFICE

This thesis has been approved for the award of the Degree of Master of Technology (M.Tech.) in accordance with the regulations of the Indian Institute of Technology Apper Dated. 14.12.73

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude to my thesis supervisor Dr. S. Ramaseshan, Professor, Civil Engineer ing Department, Indian Institute of Technology, Kanpur for his invaluable guidance, help, Gunsel and encouragement. He had very kindly spared time to solve my difficulties at various stages to bring this thesis to this shape. It has been a stimulating and rewarding experience for me to work with him.

I am deeply indebted to Er. H.C. Dhawan, Member(Irrigation Er.R.K. Bhasin(Executive Engineer), Er.I.D. Sharma(A.D.E.), and Er. Inder Sain (A.D.E.) of Bhakra Beas Management Board Nangal Township, Er. R.N. Bansal (Director Dams) and Er. J.R. Garg (A.D.E.) of Beas Design Organization Nangal Township for their advices, helpful suggestions in collection of needed data of Bhakra-Beas system for this study. I am grateful, too to my other colleagues and friends particularly Sri Kripal Singh with whom I had many useful discussions.

Last but not the least I am very thankful to my wife Smt. Manju Singh for her whole hearted co-operation, patience and encouragement throughout the preparation of this thesis.

Vijendra Singh

TABLE OF CONTENTS

			Page
List	of Tab	ples	vi
List	of Fig	gures	vii
List	of Syn	mbols, Abbreviations, or Nomenclature	viii
Syno	psis	•	xi
1.	IN TROI	DUCTION	1
	1.1.	General	l
		1.1.1. Water resources planning	1
		1.1.2. Simulation analysis	3
		1.1.3 Planning models of TWDB	7
	a	1.1.4 SIMYLD II programme	10
	1.2	Statement of Problem	10
	1.3 Objective of the Study		11
	1.4	Scope of the Study	11
	1.5	Significance of the Study	12
	1.6	Organization of the Study	13
2.	RIVER	BASIN SIMULATION MODEL, SIMYLD II	14
	2.1	Introduction	14
	2.2	Model Description	14
		2.2.1 Purpose	14
		2.2.2 Concepts	15
		2.2.3 Assumptions	22
		2.2.4 Steps	22
		2.2.5 Programme description	25
	2.3	Capabilities and Limitations	29
3.	IMPLE	MENTATION OF SIMYLD-II PROGRAMME	32
	3.1	General	32
	3.2	Modification due to Computer System	32
	3.3	Validation of the Original Programme	3.4
	3.4	Additions and Alterations	34
		3.4.1. Water Year	34

				v
				Page
		3.4.2	Canal system	34
		3.4.3	System state	35
		3.4.4	Energy	3 7
	3.5	Details of	Results from the Computer Programme	38
	3.6	Conclusion		39
4.	SIMUL	ATION OF BEA	AS SUTLEJ SYSTEM	40
	4.1	System Des	cription	40
	4.2		Representation of Bhakra-Beas-	42
	4.3	System Data Used :	in Simulation Analysis	45
		4.3.1	Irrigation demand	45
		4.3.2	Power demand	47
		4.3.3	Inflow data	48
		4.3.4	Evaporation rates	48
		4.3.5	Elevation area capacity curves	55
		4.3.6	Data for energy generation	55
		4.3.7.	Link Capacities	5 7
	4.4	Study of P	lanned Operation	59
		4.4.1	Planned operation	59
		4.4.2	Value judgements	59
		4.4.3	Results and conclusions	64
	4.5	Improvemen	ts in Reservoir Operation	65
		4.5.1	Modification of the rule curve	65
		4.5.2	Ranking of priorities	66
		4.5.3	Evaluation of system performance	68
		4.5.4	Discussion of results	73
	4.6	Conclusion	s	7 5
5.	SUMMA	RY AND CONC	LUSIONS	81
	5.1	Summary		, 8l
	5.2	Conclusion	s	82
	5.3	Suggestion	s for Future Study	83
LIST	OF RE	FERENCES		84

LIST OF TABLES

Table No.		Page
2.1	Arc Types and Definitions of Their Upper and Lower Bounds	20
4.1	Water Power Study for Dry Year	49
4.2	Water Power Study for Dependable Year	51
4.3.	Water Power Study for Average Year	53
7+ • 7+	Elevation-Area-Capacity of Bhakra and Pong Reservoirs	56
4.5	Head-Efficiency Relationships	58
4.6	Rule Curves	61
4.7	Priority Ranks for Irrigation and Power Demands	62
4.8	Priority Manks for Rule Curves	63
4.9	Modified Rule Curves	67
4.10	Power Demand at Bhakra	69
4.11	Modified Priority danks	70
4.12	Planned Energy Generation	72
4.13	Results for Simulation Run No. I	77
4.14	Regults for Simulation Run No. II	78
4.15	Results for Simulation Run No. III	79
4.16	Results for Simulation Run No.IV	80

LIST OF FIGURES

Figure No.	9	Page
1.1	Steps in Simulation	_
1.2	Procedural Planning Steps for Project II	5 8
2.1	Node Arc Configuration as a Network Flow Problem	21
2.2	Organization of SIMYLD II	27
4.1	Interconnected System of Rivers Ravi, Beas and Sutlej	43
4.2	Node Link Representation of Bhakra Beas System	46

LIST OF SYMBOLS, ABBREVIATIONS, OR NOMENCLATURE

Symbols	
ARCS	Total number of arcs in the network
C _{ij}	Cost of flow from node i to node j for time At
H	Net head
i	Index for node
j	Index for node
L ij	Lower bound of the arc from node i to node j
$\mathtt{L}_{\mathtt{B}}$	Lower limit of average state
n	Number of nodes
N	Number of reservoirs used in identifying the state of the system
$^{ m D}$	Number of demand nodes
$^{ m L}$	Number of river reaches and canals
$N_{ m N}$	Number of reservoirs and nonstorage junctions
N _S	Number of spill nodes
q _{ij}	Flow from node i to node j for time At
R	Total water available for storage or use
S	Shortage
S _i	Capacity of the ith reservoir
S _{i,t}	Desired storage for ith reservoir in tth time period
t	Period under consideration
^U ij	Upper bound of the arc from node i to node j
$^{\mathrm{U}}_{\mathrm{B}}$	Upper limit of average state
W	Total storage capacity of reservoirs defining the state of the system; Total desired storage in an average year in the reservoirs defining the state of the system.

 $X_{i,t}$ End of month storage for the ith reservoir in the $t^{\tau h}$ time frame

Fraction of W to define $\mathbf{L}_{\!B}$ lower limit of X_{7}

average state

 X_2 Fraction of W to define Up upper limit of average

state

Unregulated inflows to the ith reservoir in the Y1, t+1

(t+1) time frame

Objective function \mathbf{Z}

 \wedge t Time interval

Efficiency

Abbreviations

BBDO Bhakra Beas Design Organization

BBMB Bhakra Beas Management Board

BBS Bhakra Beas System

BDO Beas Design Organization

BMB Bhakra Management Board

BSL Beas Sutlej Link

CS Cusecs

m.a.f. Million acre feet

Million cubic meters m.cu.m.

MBL Madopur Beas Link

MMMegawatts

TAF Thousand acre feet

TWDB Texas Water Development Board

WJC Western Jamuna Canal

Nomenclature

Cumec day One cubic meter per second flowing per one day

(86400 cu.m.)

Kharif Monsoon season, June-October

Non-Kharif Non monsoon season, November-May

Rabi Dry season, November-February

Water Year June 1, to May 31.

SYNOPSIS

"Digital Simulation of Beas Sutlej System "-a thesis submitted in partial fulfilment of the requirements for the Degree of Master of Technology by Vijendra Singh to the Department of Civil Engineering, Indian Institute of Technology, Kanpur, November 1978.

Water resources systems are generally large and complex. They consist of multiple units and serve multiple purposes. The multiple purposes are not wholly complementary. Several general or problem specific simulation models and computer programmes have been developed for analysing water resources systems. SIMYLD II is a computer programme developed by Texas Water Development Board for simulating the hydrologic operation of a system of interconnected reservoirs within a basin or a multibasin water resources system. The study consists in implementing the SIMYLD II programme, validating it with available data and adapting it for the operation of Bhakra Beas system.

The original SIMYLD II programme was implemented in IBM 7044-1401 system at I.I.T. Kanpur and was adapted to meet the requirements of Bhakra Beas system.

Using 13 years of historical data, the Bhakra
Beas system was simulated using the modified SIMYLD II model.
The criteria for defining wet, average and dry years; the rule curves for operation in wet, average and dry years; and

the relative weightages for meeting different demands and for maintaining the rule curves are derived from simulation analysis. Results indicate that by using these criteria, the benefit from the operation of the system can be greatly increased. Further improvement of the model is also possible.

1. INTRODUCTION

1.1 General

1.1.1 Water resources planning

Water resources systems are generally large and complex. They consists of multiple units and they serve multiple purposes. The multiple purposes are not wholly complementary Water resources systems are designed to serve several socioeconomic objectives like national and regional economic development, income distribution, preservation and enhancement of Environmental quality and social well being (Maass et al., 1962, United States Water Resources Council, 1973). They are also affected by economic and hydrologic uncertainties.

The conventional practice in planning, design and operation of water resources projects has been to consider a set of demands and to satisfy them by river basin development. Such a development includes the purposes it is to serve, the physical means for meeting these purposes, the sizes of needed facilities and the levels of output. Based on experience, a few alternatives are proposed, analysed and evaluated through incremental analysis before a final design is adopted.

Planning can be defined as the orderly consideration of a project from the original statement of purpose through the evaluation of alternatives to the final decision on a course of action. It is the basis for decision to proceed with a proposed project and is clearly the most important aspect of

the total engineering for the project. The planning for an entire river basin involves a much more complex planning effort than that for a single project, but the difficulties in arriving at the correct decision may be just as great for the smaller project.

Hufschmidt considers the field level planning of water resources systems to consist of four hierarchical steps, viz. (Cole. 1975).

- i) Definition of project objectives and agreement of these with policy makers;
- ii) Securing staff and scheduling their tasks;
- iii) Data assembly on the physical variables (hydrology, water quality), human requirements (water supply, land use, recreation); and economic quantities (construction and operation costs, explicit benefits); and
- iv) Formulation of system design via (a) screening of alternative configurations and (b) detailed analysis of remaining components.

Planning may deal with modification to and operation of an existing system, or the design of an essentially new system involving the operating variables also. The latter is naturally more complicated. The two parts of step iv imply that initially a large number of alternatives are to be considered, and so relatively crude models are used to essentially eliminates trivial and inferior alternatives and isolate better alternatives. This is generally done by programming models.

Once better alternatives are identified, it may be possible to consider more detailed models of the system and arrive at the "best" one. This may involve stochastic programming and simulation models.

Wiener (1972) considers the role of planner and system analyst in the socio-economic development process in an under-developed country where water is used as a critical input for economic development and progress. He deems it necessary to consider the implementation phase also in planning particularly in the case of underdeveloped countries. He also indicates the limitations and opportunities in the application of system analysis and operations research techniques in water resources planning.

1.1.2 Simulation analysis

To simulate means to duplicate the essence of a system or activity without attaining reality itself. Simulation has been used traditionally in engineering. The use of conceptual system models, scale models, analogues and laboratory experimentation are but some of the general simulation techniques traditionally used in engineering. Simulation has been used for a number of purposes including the analysis of the system to estimate the parameters and the behaviour of the system that is existing or is yet to be; the effect of the environment on the system design; the demonstration of the performance of a new complex system, and for giving training in the control of complex systems.

Digital simulation is the numerical simulation of the process in a digital computer. A behaviour model of the physical components of a water resources system is formulated in terms of the components parameters, variables and relationships among them to study the processes as they evolve in time through the several components of the system when subjected to a series of hydrologic inputs and human interventions in terms of design, construction and operation of the system. When the mathematical model for a process has been decided upon, the various elements of the process can be represented on the computer so that outputs from one part of a system constitute inputs to one or more elements of the system or to itself. The system is simulated for a set of design and operating parameters, and the effect of changes in these parameters on the system response is investigated.

The simulation of any system involve generally a number of steps which can be represented as follows(Fig.1.1):

- i) Formulation of the problem: The problem is to be formulated in analytic terms. This involves the definition of the objective, their priorities, the approach to optimization, the identification of the system and its environment and the structure of the system.
- ii) Analysis of data: The historical data for the inputs, the components of the system, and the outputs are collected.

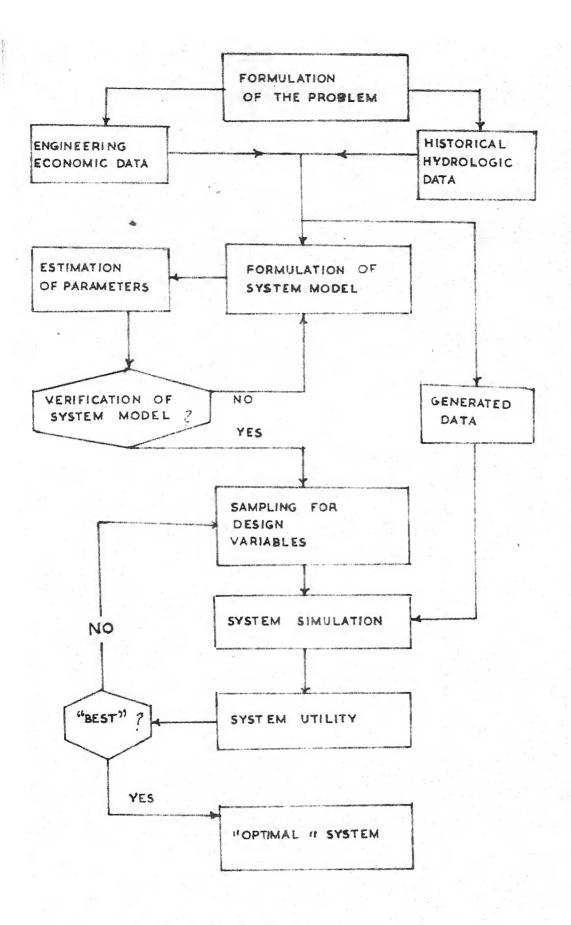


FIG. |. | STEPS IN SIMULATION

- iii) Formulation of system model: Initially component models are formulated; from the data of the previous step, parameter values are estimated for the component models; and the models are validated. A flow diagram for the system indicating the sequence of the modifications of the inputs by the system is prepared.
- iv) Estimation of parameters and validation of system model: The parameters of the system are estimated, the system is analysed or numerically simulated and from the responses of the system for hypothetical or historical inputs as per record and from the results of simulation, the formulated system model is validated.
- v) Sampling for design variables: A set of feasible and preferred design and operating parameters are chosen.
- vi) Simulation of the process: The system is digitally simulated using historical or generated data as the case may be.
- vii) System utility: The measure of system response in achieving the goals for the system parameters assumed in each case is evaluated.

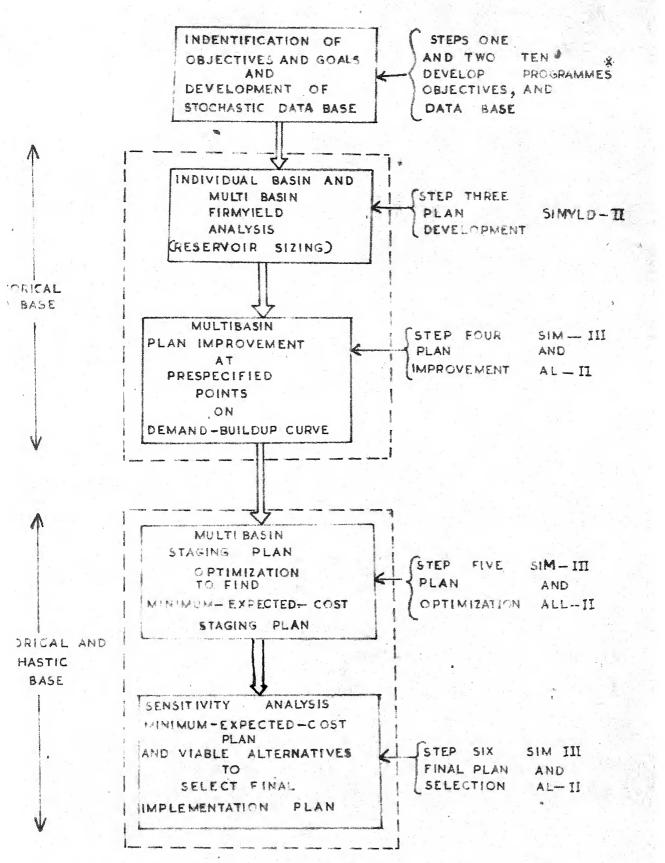
The results of simulation are also analysed to determine whether the system design can be improved with reference to the achievement of the goals. The parameter values are modified, and steps vi and vii are repeated until the "best" of the alternatives considered is identified.

viii) "Reporting of results The results of the study, the conclusions drawn and the recommended system design are reported in the final step for implementation.

1.1.3 Planning models of TWDB

Several general or problem specific simulation models and computer programmes have been developed for analysing water resources systems. Important references include Maass et. al. (1962), Hufschmidt and Fiering (1966), Lucia et al (1971), U.S. Army Corps of Engineers Hydrologic Engineering Centre (1968), and Texas Water Development Board (1972, 1972a, 1974). The general approach to simulation may be based on heuristic criteria as in the case of Maass et.al.(1962), Hufschmidt and Fiering (1966) or may use an imbedded optimisation technique as in the case of Texas Water Resources Board (1972),

Texas Water Development Board (TWDB) began in 1967 long range programme of applied research in water resources system simulation and optimization. The objective was to develop a set of generalised computer oriented planning tools for use in detailed planning, design and management of water resources systems such as the Texas Water System as proposed in the Texas Water Plan. Project II refers to the second phase of a three phase research project leading towards the development of a computer oriented planning system for use in planning of large, multibasin systems of reservoirs and connecting river reaches and pumped canals. The six planning steps of project II are shown in Fig. 1.2. They include:



51.2 PROCEDURAL PLANNING STEPS FOR PROJECTI

- Step 1: Identification of objectives and goals This step outlines the problem to be solved, specifies in general the magnitude and location of demands to be met and the priorities associated with meeting each of the specified demands, identifies the sources of the water to be considered, and identifies the criterion to be used in optimising the selection of an implementation plan.
- Step 2: Data base development In this step both historical and stochastically generated hydrologic data sets are developed concurrent with the economic and physical data.
- Step 3: Plan development This step analyses each of the individual river basins to determine their firm yield characteristics and the location of possible attractive basin import and export points.
- Step 4: Plan improvement This step improves those plans such that minimum cost plans are developed at each of several points on a prespecified demand build up curve.
- Step 5: Plan optimisation It optimises the staging plan over the time period when demands for water are increasing.

 This implies finding the minimum expected cost plan that meets the demands specified with an optimal level of shortages.
- Step 6: Final plan selection This is the final step in the planning procedure and involves testing the sensitivity of the cost and physical response of the simulated prototype to variation in all of the important parameters used by the models.

1.1.4 SIMYLD II programme

SIMYLD II is a computer programme designed to simulate the hydrologic operation of a system of interconnected reservoirs within a basin or a multibasin water resources system. The inputs to the model are physical description of the system to simulate operating criteria and monthly inflows, monthly demands and monthly evaporation rates. The output consists of monthly end of month reservoir storages, monthly flows in the system's river reaches and canals, and annual end period of simulation summaries. The main attributes of the model are simplicity in set up and use, generality in application, and speed of computation. Other models are more comprehensive and naturally much more complicated. Since SIMYLD II is used in earlier steps in decision making than the other models (Fig. 1.2) and it is also useful in identifying surplus and deficits, it is proposed to implement SIMYLD II at IBM 7044-1401 system at I.I.T. Kanpur and test it for field data of a river basin.

1.2 Statement of Problem

It is proposed to implement SIMYLD II programme developed by the TWDB, validate the programme using the test data given in the TWDB report publication on the model (TWDB,1972), adapt the simulation programme if necessary to meet the requirement of water resources systems in India, and test and validate the adapted model using some data for an Indian river basin.

1.3 Objective of the Study

The major objective of the study is to implement and adapt the SIMYLD II programme of TWDB to suit requirement of a river basin in India, identify the limitations and capabilities of such a model and hence develop knowhow for more comprehensive development planning models.

1.4 Scope of the Study

The scope of the study is limited by i) available data for real systems; ii) time availability for the study; iii) limited interactions with field engineers and planners; and iv) limitations in the IBM 7044-1401 computer system at I.I.T. Kanpur.

Hence the scope is limited to the following:

- i) Because of the limited capacity of the IBM 7044-1401 system, simulation is limited to 13 nodes, 20 links and 13 years.
- ii) The data were available for Bhakra-Beas system for a number of years and because of the limitation in time, computer capacity and computer availability, the studies are limited to the following:
- a) While Bhakra Beas Management Board (BBMB) adopt a ten daily operation of the system, only monthly operation is considered in this study;
- b) Only 13 years of data values are used in this study;
- c) Because of limitation of the data availability and non avoidable lumping of demands and supplies in the model,

certain assumptions were made with reference to allocation of demands for different sources and for the lumping of demands at nodes;

- d) The demands are defined by BBMB for dry, dependable and average years. The inflows in the system may be dry, average or wet. Certain reasonable assumptions were made to link the demands to the inflows and these are considered in great detail in Chapter 4; and
- e) Because of the limitations of the study, model needs further modification as indicated in Chapter 5.

1.5 Significance of the Study

As the remaining available uncommitted supplies of water and land resources diminish and demands for them increase, the objectives of water resources planning broaden the physical facilities required become more complex, and the limitations under which they must be implemented become more stringent. There exists an urgent need to develop techniques which can enhance the capability of the planners to make an intelligent and comprehensive evaluation of alternatives. Because costs of construction, operation, and maintenance of water resources facilities are likely to be large, a means must be found for analysing alternative solutions to water problem. Planners have been turning to sophisticated mathematical techniques applied on digital computers of increasing speed and accuracy. This study will lead to a better understanding of the problems in managing our scarce national water resource and towards a

better tool in the design of optimum water resources systems in India.

- 1.6 Organization of the Study

 The study is reported in the following sequence:
- i) Chapter 2 discusses the River basin simulation Model SIMYLD II and indicates the capabilities and limitations of the original programme;
- ii) Implementation of programme SIMYLD II is discussed in Chapter 3. Modifications, additions and alterations in the programme on IBM 7044-1401 systems to suit Indian conditions are also described:
- iii) Chapter 4 discusses the use of the adaptations of SIMYLD II in the simulation of Beas-Sutlej System. System description and input data required by the model are described briefly. A comparison is made in study of planned operation and improvements in operation. Results obtained and tentative conclusions are also discussed; and
- iv) Summary, conclusions and suggestions for future study are presented in Chapter 5.

2. RIVER BASIN SIMULATION MODEL, SIMYLD II

2.1 Introduction

SIMYLD II is a computer programme developed by TWDB designed to simulate the operation of the system of interconnected reservoirs within a basin or a multibasin water resources system. The description of the model and its various details have been taken from several publications of the TWDB (particularly TWDB, 1972).

2.2 Model Description

2.2.1 Purpose

The purpose of SIMYLD-II is to provide the water resource planner with a tool for analysing water storage and water transfer within a multireservoir or multibasin system. The model has the following uses to the planner:

- i) It simulates the movement of water in a system of reservoirs, rivers, and conduits on a monthly basis while trying to meet a set of specified demands in a given order of priority. If a shortage occurs (i.e., not all demands can be met for a particular time period) during the operation, they are spatially located at the lowest priority demand nodes;
- ii) It determines the firm yield of a reservoir within a water resources system. Firm yield is defined as the maximum demand at a reservoir that can be met with 'acceptable' shortages;

- lity in selecting operating rules for each reservoir. The operating rules are formulated as the percentage of the reservoir capacity (either total or conservation) that is desired to be held in storage at the end of each month. In addition to it, priority ranking, used to determine the allocation of water between meeting demands and maintaining storage is assigned to each storage reservoir;
- iv) The model can analyse either static or dynamic system operation, in that both constant or time-variable demands can be analysed; and
- v) The user can analyse the operation of the system under the expected ultimate demands for any selected hydrologic sequence.

The model is designed to simulate both small scale systems, such as two or three reservoirs within one river basin, and large scale systems, such as the proposed Texas Water System.

2.2.2 Concepts

The concept behind SIMYLD-II is that the physical water resource system can be transformed into a capacitated network flow problem. While making this transformation, the physical elements of the real system are represented as a combination of two possible network components — nodes and links.

As the nomenclature implies, a node is a connection and/or branching point within the network. Therefore, a node is similar to a reservoir or non-storage junction (i.e. canal junctions, major river intersections, etc.) in the physical system. Along with this, a node is a network component which is considered to have the capacity to store a finite and bounded amount of the material moving in the network. In the case of SIMYLD-II, reservoirs are represented by nodes which have a storage capacity as well as the ability to serve as branching points. A nonstorage capacitated junction is treated similar to a capacitated junction (reservoirs) except that its storage capacity is always zero. Demands placed on the system must be located at nodal points.

The transfer of water among the various network nodes is fulfilled by transfer components called links. A link is a river reach, canal, or closed conduit with a specified direction of flow and a fixed maximum and minimum capacity. The physical system and its basic time step operation, in this case a month, is formulated as the network flow problem. The network flow problem is nothing more than a mathematical representation of the physical system. This mathematical representation is accomplished as follows:

- i) Reservoirs and nonstorage junctions are represented by nodes;
- ii) River reaches and pumped canals are represented by links; and

iii) Additional information needed to describe the system, such as inflows, demands, spill points, and starting conditions are specified by the user.

An initial step in the application of SIMYLD-II is the construction of the node-link diagram describing the physical system. In designing the node-link diagram, the physical system elements are represented by diagram elements in the following manner:

- (i) Reservoirs are represented by triangles;
- (ii) Non-storage junctions or branching points are represented by circles;
- (iii) River reaches are represented by dashed lines showing the directions of flow; and
 - (iv) Canals or closed conduits are represented by solid dashed lines showing the direction of flow.

In order to make the node-link diagram conform to the requirements of SIMYLD-II, the following rules for designing the diagram should be followed:

i) Water can enter or leave the system only at node points (either storage or non-storage nodes). Inflows (over land flow, tributaries, etc.), link losses (evaporation, seepage, etc.) and demands can be lumped at the closest node. If more detail is required, additional non-storage nodes can be inserted at critical locations;

- ii) The numbering system used to describe the nodes consists of numbering all nodal reservoirs consecutively followed by numbering all non-storage nodes; and
- iii) Number all river reaches consecutively followed by all canals and/or conduits in the same manner as described above. Figure 2.1 shows this node arc configuration formulated as a network flow problem.

Once the node-link diagram is complete, all nodes, links, and other information must be described in terms of directed, capacitated arcs and nodes. Within the typical network there are seven types of nodes. These are:

- i) Reservoir nodes;
- ii) Non-storage nodes;
- iii) Initial storage and inflow nodes;
- iv) Demand nodes;
- v) Spill nodes;
- vi) Final storage nodes : and
- vii) Net balance nodes

Connecting these seven types of nodes are seven types of arcs. Flows in these arcs are constrained to be within specified upper and lower limits. The seven types of arcs are:

- i) Physical system link arcs (river reaches, pumped canals, etc.);
- ii) Initial storage and inflow arcs;

- iii) End of month desired storage arcs (operating rules);
- iv) Balance of final storage and maximum reservoir capacity arcs;
- v) Demand arcs;
- vi) Spill arcs; and
- vii) Net balance arcs.

Table 2.1. shows the arc types and their upper and lower bound constraints. The total number of arcs in any network is given by:

$$ARCS = N_L + 3(N_N) + N_D + N_S + 4$$
 ... (2.1)

Where

 N_{L} = number of river reaches and canals,

 N_N = number of reservoirs and non-storage junctions,

 N_D = number of demand nodes,

 N_{g} = number of spill nodes, and

4 = number of balance arcs.

cost per unit of flow is associated with each arc in the network. These unit cost coefficients are used to find the minimum cost solution to the network flow problem. As input to the model, the user selects priorities for meeting demands and satisfying final end-of month storage requirements in the reservoirs. These priorities are then converted into the above mentioned costs by the programme. Demand arc and desired storage arc costs are expressed as negative costs (analogous to benefits). The more negative

TABLE 2.1 ARC TYPES AND DEFINITIONS OF THEIR UPPER AND LOWER BOUNTS (TWDB, 1972)

	Arc Type	Lower Bound	Upper Bound
1.	Physical system link		
a.	River Reach	Minimum River Capa- city+ (User Specified)	Maximum River Capacity
b.	Canal, Pipe line	Minimum Canal Capa- city+ (User Specified)	Maximum Canal Capacity
2.	Initial Storage and Inflow	Previous End-of- Month Storage Plus Current Monthly Inflows	Previous End-of- Month Storage Plus Current Monthly Inflows
3.	Final Desired Storage	Reservoir Minimum Pool (User Specified)	Percent of maximum Capacity Desired (monthly operating rules)
4 •	Final Storage Balance	Zero	Balance Between Maximum Capacity and Upper Bound of 3.
5.	Demand Arc	Zero	Demand at Node.
6.	Spill Arc	Zero	System Capacity Multiplied by 10
7.	Net Balance		
a.	Total Initial Stora- ge Plus Inflows	Σ Initial Storages	Σ Initial Storages
ъ.	Total Final Storage Arc	Σ Final Storage Bala ce Plus Σ Final De- sired Storage	
c •	Total Demands	Zero	Σ Demands
d.	Total Spills	Zero	Σ Spills

⁺ Should be zero unless minimum flow is required. However a minimum flow requirement may cause infeasible solutions.

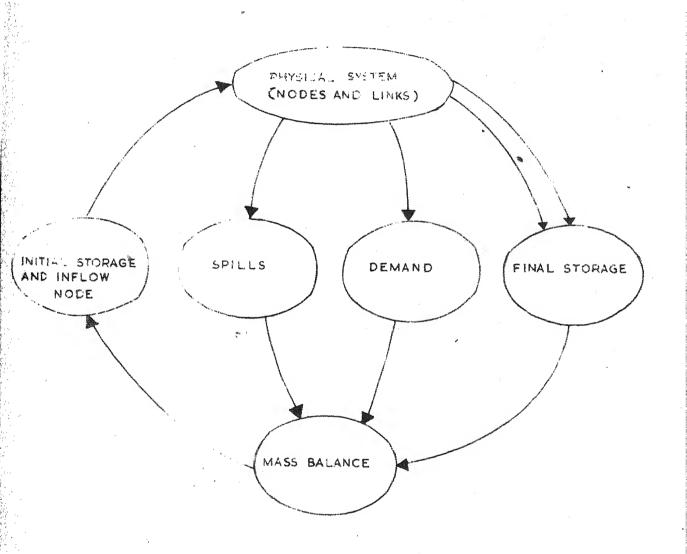


FIG. 2.I NODE ARC CONFIGURATION AS A NETWORK FLOW PROBLEM

the number, the higher the priority for meeting the upper constraint (demand or storage). Physical system link and spill costs, on the other hand, are positive costs. The effect is to meet demands and desired storage in the order of the priorities while minimising the canal pumping and spills from the system. It may be noted that high rank indicates the lower priority and vice-versa.

2.2.3 Assumptions

- i) Evaporation losses for all reservoirs are calculated by the product of the monthly evaporation rate and the aver monthly reservoir surface area;
- ii) Demands for water are known for the month being simulated:
- iii) Unregulated inflows to the system are known for the month being simulated:
- iv) Reservoir storage contents are allowed to fluctuate between the maximum and minimum capacities specified by the user;
- v) Spills occur only at specified nodes and are the mos expensive alternative; and
- vi) The flow in all links ranges between the maximum and minimum capacity specified by the user.

2.2.4 Steps

The procedure adopted in the programme makes use of the following four steps in moving from a known set of state variables at the beginning of a time step to the solution for the required set of state variables at the end of the time step. The four solution steps are summarized as follows:

- i) The present status of the network is evaluated and all system elements are given an appropriate parametric description;
- demands are accounted for, and the mass balance for the entire network system is determined. Bounds are placed on system demands, spills and storage levels.
- iii) The flows necessary to meet the levels required by (Eq. 2.3), and at the same time minimise the system's total cost of water transport, are determined through the application of an optimisation procedure.

The mathematical formulation of the directed capacitated network problem is as follows:

MINIMISE:

$$Z = \sum_{i,j} q_{i,j} C_{i,j} \qquad \dots \qquad (2.2)$$

Subject to :

$$\sum_{i} q_{ij} - \sum_{i} q_{ji} = 0, \quad j = 1, \dots n \qquad \dots$$
 (2.3)

$$L_{ij} \leq q_{ij} \leq U_{ij}$$
, all i, j ... (2.4)

where

 $q_{i,j}$ = Flow from node i to node j for time $\triangle t$;

L = Lower bound of the arc from node i to node j; and

U_{ij} = Upper bound of the arc from node i to node j

The first set of constraints (Eq.2.3) satisfies continuity of mass at all nodes in the network. Eq. 2.4 describes the upper and lower limits on flow in all arcs in the network. The objective function to be minimised is expressed by Eq. 2.2.

and the status of the system at the conclusion of the current time step becomes the status at the beginning of the next time step.

This procedure is repeated in a step-wise fashion until a specified simulation interval has been spanned.

In SIMYLD-II the optimal allocation of network flows is accomplished through the application of the "Out-of-Kilter Algorithm" (Ford and Fulkerson, 1962). This procedure finds the minimum total cost of water circulation within the network system subject to flow constraints placed on the system arcs. If we define the amount of water flowing in arc (i,j), from node i to node j, as $\mathbf{q_{ij}}$, and the unit cost of moving water in this link as $\mathbf{C_{ij}}$, then the algorithm minimizes the objective function $\mathbf{7} = \mathbf{\Sigma} \ \mathbf{C_{ij}} \ \mathbf{q_{ij}}$ for all i and j in the system. This is accomplished subject to the flow constraints given in Eqs. 2.3 and 2.4. The 'Out-of-Kilter Algorithm' requires

the objective function and all constraints to be linear and therefore, SIMYLD-II can be considered to be a linear programming formulation.

2.2.5 Programme description

SIMYLD-II consists of a main programme and eleven subroutines, all of which are written in Fortran IV programming language. Fig.2.2 shows the organization of the code the subroutine names and calling programme.

The following is a description of the important features of each of the subroutines.

SIMYLD-II (Main Programme)

The main programme is the control point for calling subroutines. The Fortran logical unit requirements are
read in and their values are kept throughout programme execution.

Subroutine ADJUST

This subroutine is used to adjust the annual demands in the firm yield calculations. This adjustment is based on the greatest shortage incurred during the period of operation. When the shortage demand ratio is within the user specified tolerance, or the preset value of 10 percent, it returns to subroutine OPRATE with input = 0 value.

Subroutine CARDS

Subroutine CARDS reads all input from Cards except for the monthly variable data(inflows, demands, and evaporation rates).

Subroutine DATA 1

This subroutine is called only if variable monthly data (inflows, demands, and evaporation rates) are being read from cards. The data cards are read, rearranged, and a temporary scratch file is written for use by the programme. ENTRY DATA 2

This entry point within subroutine DATA 1, permits the programme to read one year of monthly data during simulation. The temporary scratch file is written from a previous call to DATA 1 or is created in advance.

ENTRY RULE

This entry point is where the monthly operating rule criteria is set. The preselected subsystem of reservoirs is analysed to determine if it falls in the average, dry, or wet state and the appropriate operating rule is passed on to OPRATE.

Subroutine OPRATE

This is the major subroutine in the programme and is where the yearly and monthly loops are set and all calls to operating parts of the model take place. The arc

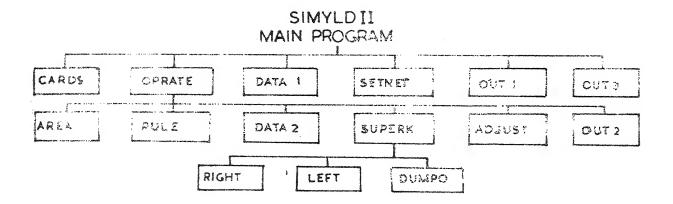


FIG. 2.2 ORGANIZATION OF SIMYLD II

bounds and unit flow costs are calculated in this routine. This subroutine also controls the calls to ADJUST and DATA 2 for iteration if the model is operating in the firm yield mode. Upon return from the network flow algorithm, initial arrays and yearly total summaries are set up. Base on an input operation selected years are passed on to OUT 2 for printing.

Subroutine AREA

This subroutine performs a linear interpolation to determine reservoir surface area as a function of volume. The user is permitted to input up to 18 matched points per reservoir to describe the area - capacity relationship of each reservoir in the system.

Subroutine OUT 2

OUT 2 prints detailed monthly system operation for selected years. At the end of each simulation year, OPRATE determines if the year should be printed and issues a call to OUT 2. Detailed monthly information for each node and link is printed including beginning and ending storages, inflows, demand, spills, transfer amounts, etc.

Subroutine OUT 1

This subroutine provides a complete printing of the input variables that control the simulation. These variables have been read previously by subroutine CARDS.

Subroutine OUT 3

Subroutine OUT 3 is an output subroutine called from SIMYLD-II (Main Programme) after the simulation is completed. This subroutine prints summaries of the annual operation of each node for each year in the simulation period. In addition, simulation period totals and maximum and average flows in each link are printed.

Subroutine SETNET

This subroutine is called to set up the basic network system. The configuration is determined by the number of nodes and physical links which are joined to mass balance nodes by artificial links as described previously.

Subroutine SUPERKIL

This subroutine finds the minimum cost flow in the network. As described previously, costs are determined from the ranking priorities supplied by the user. The routine is called by OPRATE for every month of simulation where the bounds and priorities have been assigned.

Subroutine RIGHT Entry LEFT

This subroutine and entry point are intimately related to the operation of the subroutine SUPERKIL.

2.3 Capabilities and Limitations

SIMYID-II is capable of simulating the operation of a system of interconnected reservoirs and non-storage

junctions with a maximum of 30 nodes (reservoirs and non-storage junctions) interconnected by a maximum of 45 links. The maximum simulation period, using monthly intervals is 30 years.

Unit identifications have been purposely deleted from output files so that the model can use acre-feet, thousands of acre-feet, metric system units, etc. as units of flow and storage as required by the user.

The model allows for three sets of operating policies to guide the model through corresponding hydrologic states. These hydrologic states are determined by the programme each month from the value of storages and inflows in a specified group of reservoirs.

The model accepts card input for the monthly data for a system consisting of upto 20 nodes and for a simulation period of less than 21 years. For larger systems or longer simulation periods, a binary tape must be prepared.

In some cases, the algorithm in SIMYLD-II causes the simulation to be terminated due to infeasibility in solving the network problem. In almost every case, these infeasibilities are caused by in proper specifications by the user. The most common are:

- i) Improper system configuration;
- ii) The user has not allowed an adequate number of spill nodes;

- iii) A minimum canal capacity is too binding;
- iv) An unregulated inflow occurs where there is no possible way to reallocate the water in the system, that is, no spill node has been provided, and
- v) Basic data problems

Most of the above problems, can be readily avoided by carefully examining the schematic diagram and verifying that the data are correct.

3. IMPLEMENTATION OF SIMYLD-II PROGRAMME

3.1 General

SIMYLD-II is a fairly lengthy programme involving around 1400 FORTRAN Cards. Available core memory in IBM 7044 at I.I.T. Kanpur is less than 32 K. words. This is not adequate for the original SIMYLD-II programme. Two compilers are available for IBM- 7044 viz. (i) WATFOR, (ii) FORTRAN IV. WATFOR Compiler gives an extensive diagnostic report but memory availability is less and diagnostic checking is slow. Due to memory problem, and even for debugging purpose, the whole programme could not be run at a time. Main programme and each subroutine were fed separately on WATFOR compiler for correcting the syntax errors.

3.2 Modification due to Computer System

SIMYLD-II was developed by Carles D. Puentes of the Systems Engineering Division of the Texas Water Development Board on a third generation Computer System. This is to be implemented in the IBM 7044-1401 system at I.I.T. Kanpur using Fortran IV compiler. While correcting the syntax errors of main and subroutine programmes, problems arose:

- i) The notation for continuity card is changed from Λ , B, C etc. to 1,2,3 etc. to suit the computer system;
- ii) Entry statements were used in the original programmes e.g. ENTRY DATA 2 and ENTRY RULE in Subroutine DATA 1 and ENTRY LEFT and ENTRY DUMPO in subroutine RIGHT. Since entry

statements are inadmissible in the IBM 7044- 1401 system, the following modifications were made to the programme:

- a) Since ENTRY DATA 2 and ENTRY RULE which occur in subroutine DATA 1, are called only once each and that too in subroutine OPRATE, those were incorporated in subroutine OPRATE itself:
- b) ENTRY LEFT and ENTRY DUMPO have been implemented as separate subroutines:
- iii) Some read cards had to be changed to suit the computer e.g. READ(KIN, 11, END = 22) (TITLE (I), I=1,20) was chaged to ASSIGN 22 TO LOC

CALL FXMSET (LOC, IFLAG, -7,38)

READ (KIN, 11) (TITLE (I), I = 1,20)

iv) After removing the syntax errors, the complete programme was fed and it was found to result in large memory overflow. The original programme is capable of simulating the monthly operation of a system of interconnected reservoirs and non-storage junctions with a maximum of 30 nodes and 45 links over a period of 30 years. In order to reduce the memory requirements to the capacity of IBM 7044-1401 system, it was necessary to reduce the dimension of the variables. It was found that a system with 13 nodes and 20 links can be simulated using monthly intervals over a period of 13 years.

3.3 Validation of the Original Programme

The original publication describing SIMYLD-II (TWDB 1972) gave the test data for a hypothetical system and the programme was run using the test data. The results from the simulation run agreed with the results given in the original publication and thus the programme implementation was validated.

3.4 Additions and Alterations

3.4.1 Water year

In the original programme the water year is counted from first January to thirty first December. In this study, the water year is modified to begin on June Ist of one year and ends on the thirty first May of the next year.

3.4.2 Canal system

SIMYLD-II considers man made and pumped canals which are costly. Hence these are to be avoided and so the original programme minimized pumpage cost for canal flow. In certain systems e.g., Bhakra Beas System, diversion may be preferable because of an existing high head reservoir and resultant flow through an additional power plant. Further more the unit cost of flow in the river reach and canal were taken as one in both the cases. In the revised programme, the cost of the river reach is kept as one while for the canal it is ten and the programme was modified so that it may not

minimize canal diversion. This requires identification of some river reaches where diversion is Undesirable as canals and vice versa.

3.4.3 System state

The operation of the system depends upon whether storage and inflow in a given month indicate the water available to be below, at or above average conditions referred to respectively as dry, average and wet states. The states are determined as follows:

 $\boldsymbol{\Lambda}$ specific group of reservoirs are used to identify the system state.

Let

number of reservoirs used in identifying
the state of the system
the number of reservoirs in the system
the period under consideration
the

= capacity of the ith reservoir

X_{i,t} = end-of-month storage for the ith reservoir in the t th time frame

Y
i,t+l = Unregulated inflows to the ith
reservoir in the (t +1)th time frame

W = total storage capacity of reservoirs defining the state

 $= \sum_{i=1}^{N} S_{i}^{!}$

$$R = \sum_{i=1}^{N} X_{i,t} + \sum_{i=1}^{N} Y_{i,t+1}$$
 (3.1)

Let X_1 and X_2 be fractions of the subsystem maximum capacity used to determine the limits of the hydrologic state with $X_1 \leq X_2$. Define

$$L_B = X_I W \text{ and}$$
 $U_B = X_2 \cdot W$

where the hydrologic state is determined by

$$R < L_B$$
 = DRY
$$L_B \leq R \leq U_B$$
 = AVERAGE , and
$$R > U_B$$
 = WET

Associated with each one of these hydrologic states there is a corresponding set of operating rules and ranking priorities for meeting demands.

Based on input parameters supplied by the user for the operation of reservoirs and priorities, the programme optimises the reservoir releases.

In SIMYLD-II the decision about the states were made monthly but in India with a highly seasonal inflow, the state of the system does not generally vary in the non-monsoon season. For example the decision concerning the Bhakra Beas System are generally modified month after month (or every ten days) in the filling season but may be considered as constant in the nonfilling season. Hence the programme

has been modified to define and evaluate the state in the months of June, July, August and September and use the state in September for all subsequent months until next June.

As rule curve values change from month to month, it was necessary to define W in terms of desired storage in an average year rather than the total storage. Hence
W was redefined as

$$W = \sum_{i=1}^{N} S_{i,t}$$
 where $S_{i,t}$ is the desired storage

for ith reservoir in tth time period for an average year as per the rule curve.

3.4.4 Energy

SIMYLD-II programme was developed to consider the demand for water, say for irrigation, water supply, etc.

While irrigation is the major purpose of Beas Sutlej system, the energy needs are also important and it is necessary to keep track of the energy generation from month to month as well as seasonal and annual deficits in energy. Subroutine ENERGY is added to suit the specific requirement of the Beas Sutlej system and using the specific 'Elevation-Efficiency - Storage ' relationship of the system. It may be noted that for other systems the subroutines will need modification.

3.5. Details of Results from the Computer Programme

The output from SIMYLDII consists of three subreports as follows:

Sub-Report 1

This sub-report contains the information supplied by the user for the simulation and includes the number and description of the nodes, links and configuration of the system.

Sub-Report 2

This sub-report gives details informations as the nodes and links on the monthly basis and this includes initial storage, unregulated inflow, upstream spills, demand, surface area, evaporation rates, evporation losses, downstream spills, shortages, pumped into, pumped out, system loss, end of month storage and operating rules for each storage reservoir, demand, storage, and unregulated inflow for each non-storage nodes, and actual flows in each link and the annual average. This is repeated for every year.

Sub-Report 3

This sub-report provides a series of summaries the period of simulation and also for every year of simulation for each node and for each link.

3.6 Conclusion

It is possible to implement the original SIMYLD-II in IBM-7044 system and adapt the programme suitably though modifications and additions in order that Bhakra Beas System can be simulated. Final results considered in Chapter-4 indicate that further modifications should be made in the programme in order that it is more realistic. However the experience with SIMYLD-II indicates that when a large number of computer programmes are available for simulation of water resource systems, it may be easier to adapt some of the existing programmes than to write a new programme particularly when the systems are complex and not well understood.

4. SIMULATION OF BEAS SUTLEJ SYSTEM

4.1 System Description (Bhalla and Bansal, 1975, , Mehindiratta and Hoon, 1973 a, Harbans Singh, 1964; BBDO, 1964).

The Beas Sutlej system (Shown in Fig. 4.1) has been chosen for the study. The river Sutlej, which originates in the regions of Mansrover in Tibet, enters Indian territory near Shipki and after flowing for a length of about 200 miles, it emerges in the plains of Punjab at Bhakra. Total catchment area of Sutlej above Bhakra Dam is about 21,960 sq.miles and of this 14,305 sq.miles lie in Tibet and only 7655 sq.miles lie in India.

The Sutlej catchment is affected by summer rainfall as well as winter rainfall. The period of south west monsoon rainfall extends from June to September, and winter rainfall extends from December to February. Rainfall in the catchment varies over the basin with an annual average of around 875 mm. Govindsagar, the reservoir formed by the Bhakra dam has a gross capacity of 7.644 m.a.f. and a live storage capacity of 5.932 m.a.f. above a dead storage of 1462 ft. It covers an area of 41,000 acres. The total runoff at Bhakra for a dependable year works out to 11.128 m.a.f. and that for a mean year to 13.329 m.a.f.

Water from Govindsagar can be passed through turbines of two power houses, one on the right bank and the other on the left bank at the foot of the Bhakra dam. Both the power

houses have 5 turbines each. Each of the generators in the right bank power house has a maximum capacity of 120 M.W.where—as each of the left bank generators has a maximum capacity of 90 M.W.

About 11 kms. downstream of Bhakra dam is Nangal reservoir formed by the 95 ft. high Nangal Dam. Part of the water from Nangal is released to Nangal hydel channel with a length of 40.07 miles and a carrying capacity of 12,633 cusecs. The remainder of the water is released to Sutlej. The Nangal hydel channel supplies water to two power houses on its path at Ganguwal and Kotla with a total installed capacity of 154 M.W. Water from the Nangal hydel channel is then divided between the Bhakra main canal and the Sirhind Canal.

Downstream of Nangal, there are head works at two places on the river Sutlej at Rupar and Harike. At Rupar water is diverted to Bist Doab and Sirhind Canals.

The Beas river takes off from the lower ranges of Shiwaliks and joins the river Sutlej at Harike. The total length of its course upto its confluence with River Sutlej is about 247 miles and the length upto Beas Dam at Pong is 143 miles. The catchment area of river Beas upto Pong is approximately 4,850 sq.miles. The average rainfall in the catchment is 1,778 mm. For a mean year the discharge at Mandi Plain varies from 5,328 cusecs minimum in the dry season to 65,350 cusecs during monsoon, with an annual average runoff of

13.01 m.a.f. For a dependable year, the runoff is 10.00 m.a.f.

Beas project has been undertaken for harmessing the water and power resources of the Beas river by means of storage and diversion works. It consists of (i) Beas-Sutlej link, which comprises a diversion dam at Pandoh across the Beas in the Kulu Valley to transfer 3.83 m.a.f. of water to the Bhakra reservoir through tunnels and open conduits capable of passing a maximum discharge of 7500 cusecs and (ii) Pong dam which provides for a storage dam at Pong with a maximum height of 432 ft, a gross storage of 6.952 m.a.f. and a live storage capacity of 5.908 m.a.f. The power plant has 4 units with an installed capacity of 60 M.W. each with provision for two additional units in future. The water released from Pong dam and utilised for generation of power will be used for irrigation through the Beas Canal system from the Harike head works. Water from the Ravi river is transferred by diversion at Madhopur head works through Madhopur Beas link (maximum capacity 10,000 cusecs) to the Beas river. This can be diverted at Harike to irrigate Beas command. The interconnected system of the Beas, Sutlej and Ravi rivers is shown in Fig. 4.1.

4.2 Node Link Representation of Bhakra-Beas System

For the consideration of the study the Beas-Sutlej system may be considered to consist of the following:

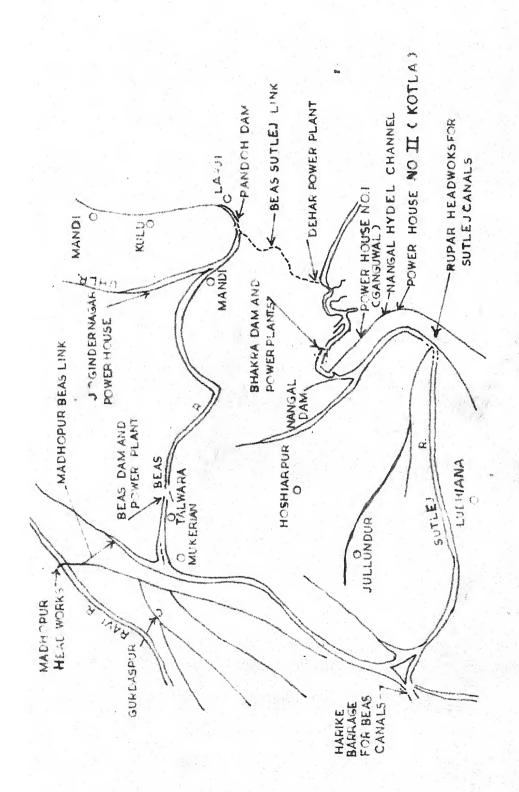


FIG. 4-1 INTER CONNECTED SYSTEM OF RIVERSRAVI, BEAS AND SUTLEJ

Two reservoirs at Bhakra (1) and Pong (2) and diversion point without storage at Pandoh (3) and five control points without storage at Dehar (4), Nangal (5), Rupar (6), Harike(7) and Mukerian (8). It may be noted that Nangal reservoir has a small storage capacity with reference to releases in a month and it is used for within the week and within the day balancing of demand and inflow. Hence the fluctuation of storage at Nangal is ignored in the study, and Nangal is treated as a control point without storage.

The number within the brackets is the serial number of the node with reservoir numbered first and other nodes later. The numbering of the river reaches and canals were done initially by treating the diversion canal as a canal and river reaches as river reaches. However because of the formulation of the original programme which minimises canal diversion, this formulation resulted in large diversion through Pong and small diversion through Dehar and Bhakra.

The inflow in river Beas may be diverted through Beas-Sutlej link for augumenting storage at Bhakra and hence to generate power at Dehar and Bhakra or permit to flow through Beas river to Pong, but diversion is always preferable and so flow from Pandoh to Pong is desirable only if the inflow at Pandoh is larger than the capacity of Beas-Sutlej link canal or when there is no storage available in Bhakra. Hence for the system model used in the study, Beas-Sutlej link is considered

as a river reach with a high priority and Beas river between Pandoh and Pong is considered as a canal section with a low priority and is numbered last as shown in Fig. 4.2.

4.3 Data Used in Simulation Analysis

Simulation analysis of Bhakra Beas system needs extensive details of data concerning the reservoir, canals, power houses, demands, inflow and priorities. Those have been obtained from Bhakra Beas Management Board (BBMB) and from a number of publications (BBDO, 1964) and include the water power studies of BBMB for cycle point 1921-22 to 1959-60. A brief description of the data used in the study are given in the following subsection.

4.3.1. Irrigation demand

The irrigated area served consists of parts of Punjab, Haryana and Rajasthan. The main crops grown in this region are bajra, cotton, maize, rice, jowar, sugarcane, oil seeds, pulses, potatoes and fodder during rabi season.

Beas Design Organization (B.D.O.) has estimated the demands for various command areas of the Beas-Sutlej system for dry, dependable and average years. A part of the demand is met from outside the basin including western Jamuna canal and the planned operation of the system for dry, dependable and average years are given in Tables 4.1, 4.2 and 4.3.

The requirements are low in the months from December to April except in the latter half of February and in March

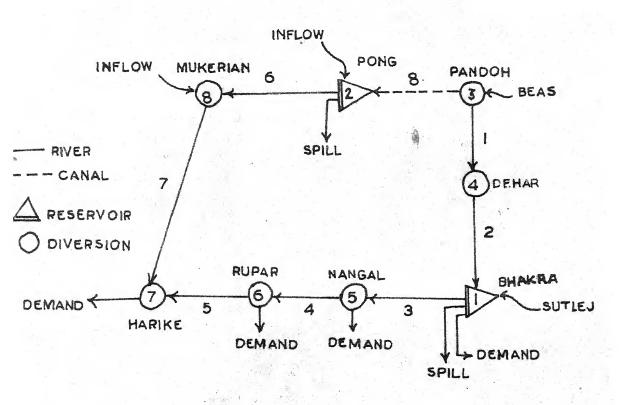


FIG. 4.2 NODE LINK REPRESENTATION OF BHAKRA BEAS SYSTEM

when water is required for maturing of rabi crops. The requirements are high in the months from September to November owing to water required for maturing of Kharif crops and preparation and sowing of Rabi crops. Rabi crop requirements are less than Kharif crop requirements. In the months of May and June, the requirements are again high due to preparation and sowing of Kharif crops. In the monsoon season also the requirements are quite high as the areas where such water is to be utilized, have low rainfall.

In the absence of additional prior information, the year is identified in this study as dry, dependable or average and the net corresponding B.D.O. demands were used in simulation analysis.

4.3.2 Power demand

The releases from the reservoir were originally planned to be made mainly in the interest of irrigation. Water is released in the interest of power from Bhakra reservoir only. These releases were to be in addition to those made in the interest of irrigation. Only 0.154 m.a.f. was earmarked for releases to be made to firm up power generation from Bhakra for average year while 1.084 m.a.f. and 1.099 m.a.f. was planned to be released in the interest of power for dry and dependable years respectively. The details of releases in the interest of power are also given in Tables 4.1 to 4.3.

4.3.3. Inflow data

The Beas-Sutlej system receives inflows from Sutlej at Bhakra, from Beas at Pandoh and Pong, and from Ravi-Beas diversion and Beas inflows at Mukerian. Inflow data for river Sutlej at Bhakra and for river Beas at Pandoh and Pong are available for ten daily periods for a large number of years.

In this study monthly data for only 13 years from June 1961 to May 1974 were used to derive the Sutlej inflow at Bhakra, Beas inflow at Pandoh and the additional inflow between Pandoh and Pong lumped as Pong inflows.

Rivers Ravi and Beas are interlinked through M.B.link of 10,000 cs capacity. B.D.O. recommended inflow at Mukerian through M.B. link for dry and dependable years as 1.442 m.a.f. and for the average year as 1.949 m.a.f. Details for monthly values are shown in Tables 4.1 to 4.3.

4.3.4. Evaporation rates

Evaporation occurs from the reservoir, channels and irrigation areas. Evaporation from irrigated areas is included in irrigation demands, but the losses from reservoir storage due to evaporation constitute a consumptive use and are not available for other uses. Hence they are to be estimated for Bhakra and Pong reservoirs. Mehndiratta and Hoon (1973) measured the pan evaporation at Bhakra from April 1966 to March 1971 and estimated the evaporation rates from inflow, outflow and storage data. They estimated an average pan

-DEHAR POWER PLANT

Period	Intium of River Beas at Pandoh for diversion to B.S.L. (CS)	Supply diverted through B.S.L. limited to 7500 CS 'Q'	Furlrace Elevation (ft)	67055 head available (2760—Col.+) (ft)	Head head 10.762 × 10.6 × Q.2 (ft)	Head 1055 in Penstock (ft)	Total Recid 10.55 (ft)	8	Mean head (ft) 2760 - Col. 8-average tailrace Elevation	Efficiency 'e'	Power in M.W Q.H. E 11800	Inflow of River Beas at Pong (CS)	Supply diverted to B.S.L as in col 3 (CS)	inflow of River Beas at Pong after diversion at Pandoh ((of 13-CO/14)	Requirements of Punjab Canals at Harike
ATTENDED OF THE PARTY OF THE PA	2	3	4	5	6	7	8	9	10	11	12	13	14	15	15
n (Margaellandia ang 20 MG) (m. 15 n Arris to the transport of the support of the	No. Landingsfreigheite Bergeberteite Landingsbergerichte Aufgestelle Aufgeberteite der Bergeberteite Aufgeber Mit Geworden Bergebergerichte Bergebergerichte Aufgebergerichte Bergebergerichte Bergebergerichte Aufgeber der Aufgebergerichte Bergebergerichte Bergeb			- Transport of the Control of	Transfer of the National Association of the National Assoc	Боловой надруживания домов наповарання на водина В на 19 поставлення на поставления на 19 година В на 19 поставления на поставления на 19 година		umaghagigi (1904-1909) ya 15 afgirini mata iya gili (1904-1909) hayin gili aggiri agiri (1904-1904) da cafaqana, da ilgir (1906-1909) mata (1906-1909)		A Committee of the Comm	galf de Self filosop i y gronn palas militaris (color signatur) e signatur de 1/8 Timb perminentamente mentemberatur (color 2/19 i 4 timber	graphics in the factor of the Control of the Contro			A description of the second sec
and the state of t	18827	7500	1050	*	43	25	6 3	terminalisasje il i i stranov eve eminerit	1042	1	530	28314	7500	20814	7007
August	15 +31	7500	1650	Management to creating to the past or a plane described in a past of the past	4-3	25	68	das may an met prate sent resource de la companya de di Van spilli	1042		530	22007	7500	14507	7007
Sci f 110	1156	7500	1650	ommun, muddinininustriitittitä (ommunusususususususususususususususususus	4-3	25	68	gud Záng, Lundskögy, handyahnap an- sabanyummarsudostylij	1042		530	18120	7500	10620	7154
distribution de la company de la company de la company de la company de la company de la company	District Section 2017 of the section	7500	1650	Big. 1770 Big. 198 Printerskill Big. 1, G. aks allgebreveningen. Printerskill III (1888)	4.5	25	68	ette tilgagagatat somanismannisk i et som upptimanter a Tilgagatat	1042	and the state of t	530	13590	1500	6090	7154
5cpt 2130	6326	5.326	1650		30	22	52	decembers a anapagaans va an Existina ansista da an	1058	A CONTRACTOR OF THE PARTY OF TH	455	11018	6326	4692	7154
DCT.	4450	4450	1650	fathrationsementament in the control of the control	15	16	31	e te disebit dile. L'iviggiè i repi paparinal lagravas al	1079	Management of the second control of the seco	397	7684	4450	3234	4602
MOV.	3113	31.13	1650	Comments are the president and	Transcent Spirit Arabotamic p	15	22	t in	1088	Bernard der an Britanis der Australia	230	1-156	3113	1643	4602
Dec.	21.75	21.75	1650	1110	annon pro più ar pallaberanopum er a ri consessibilità de la consessibil	15	19	englesedentroom neede / v suudrakkenannin	1091	0.8	161	3715	2175	1540	3217
Mataparakan yani anggaran mangaran makan danga kanasar nagaran dangaran danggaran dang	Vindillikku - 'n verskappenmainne yngskrappi, jeg j.j., i vil li lindillik	a de la companya de l	perc / 1 Pr 1 Day / Information made by a separate block and a secure		entination (1.03 depletination de translation de la company de la compan	i B The state of the state of t	Royaldown ordenskila galaridakka palakon ya - Vivila ya masa ya kalifa	rakoning ***** Anderson keun kenonakankan dan bahasa	eggard vargeng francoskrift, als group for Ford Principles to a successful		The state of the s	- Paran na rakijiki — rispanjaha a Judi dijakisih kuri tangkaranakan panjasa a angangan p			
Jan.	1796	1796	1650		2	15	17	dar valefyllenskylderskapskerkenskerkenskerkelskilder	1093		133	2622	1796	826	2557
Feb	1928	1928	1650	and the second of the second o	3	15	18	hirishishmaahida wakaranga dipangantsia	1092	andrakar-ciae Carin orang paramakanan pil-aganan	143	3193	1928	1265	3379
Mar	2809	2809	1650		G	15	2.1	n dr. J. Amellikon de y prinsipaliki ilijanje p. 1. 1920.	1089		208	4108	2809	1299	3835
Apr.	3519	35 19	1650		9	15	24	hadha ata - korppia rasophulusususus raysigi	1086		260	4194	3519	675	3469
May	7144	7144	1650		39	24	63	ert vi anderssen (subservendisk, grativan	1047	nacio di nacionale puntamenta de la companio de la	509	8090	7144	946	6790
June1-10	9440	7500	1650	Personal Amelika - Personal Amel	43	25	68	disco-promonent i i reducente describino	1042	W1.000	530	11680	7500	4180	6190
11-20	11484	7500	1650	taulur in Alemanna i residente de la constantina del constantina de la constantina de la constantina del constantina de la constantina de	43	25	68	t fall i genedlere i felitesgrus-vesintyspeleselig	1042		\$ 80	12611	7500	5111	6790
21-30	16634	150C	1650	V	in 3	25	68	angua manananin 3,44-72 (Singgabili 9) apililagandaran	1042		530	15118	7500	7618	6790
M.A.F	and the second s	3.611	kantitisen (*). 1 kirist tillikaantitise riimikkaapananakkaniese (*). 1 k. instansi	Mathyu - Town A Angelone y Assertan and Constitution and Angelone and			American Company of the Company of t	 * * *********************************		and the second second second second	r etterformalismus er sommenmen krimeti i sjærfer ett upp 1 seppe	7.104		3.653	3.681

Penjub Canuls at lanke after ye clepter on period at 50% (1.5)	Requirement of Rejesthen canals at Harike	Rain Canals at Harike after applying R.F. darring a pleiner	Personal Supply to Personal Ray, Canale at Harrike (COLITY COLITY (CS)	Releases mudit shorked to make (cs) (cs) 45 Succeed to	Wase : retween	Net Supplies delivered at Harike trem Bhakra (col. 21-col. 22)	Met Supply avuillable through Median Sins at the sink (cs)	Releases mule in the interest of	Gean of foss between perion	Total releases al Pomy Co. Col.20-(Col.23+Col.24 +Col.26) (Co.	1 2 3	Storage or with drawer without acre teet (FAR)	Losses in Peng Rescryon in acre feet	Net Storage III Pang Rescryott	Reservoir Elevation (ft.)	Tailrace Flevation (fl)	Gross head (H.)
Control of the Contro	The second of th	A CO	20		22	23	24	25	26	27	28	29	30	31	32	33	34
and argue to an total anteres mark more	yn 1971 maeun de benedig a sall y en beken ar en en best en betek	1 magazinos, 19, d 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	The functional property of the second	MC-101 (1) (1) (1) (1) (1) (1) (1) (1) (1) (1		mer artin statis unique i 10 i identificação mensión (10 de 10 de 10 Pros stê ilha	ansath	The second materials and second		entre vest en ter-men. et 4 menen energelijkligtigentlijkelijde	maggina	The second control of	and the second sec	1044	1260		Application () September 1 September 1 September 2 Jan 1 September
760 F	12/36	10140	10147	Sources been and a second seco	West of the second seco	, delle in somerestament, girs, i rugalica d * male	9000	f. 1 1 10 200 10 2 10 10 1	+1500	9647	+11167	+692	15000	1721	1289	1088	
7000	15140	73144	20247	1734e		. The sector decorded to the decommendation of the sector decommendation o	9000	rent of manufactures	+1500	9147	+4860	+301	15000	2007	1298	1088	(2) C
	14834	12460	27606	6 703		6453	24	3	F1500	10370	+ 250	+ 5	5900	2007	1298	1086	210
3577	Elipias.	Company of the Compan	100 %	None of the second of the seco	100.00	neder to an appropriate and school of the	anger -	e see see see see see see see see see s	71500	8528	- 2438	45	5000		1297	1087	57 (5)
agains an art anna an a	\$19.80	5055	: 8164}	THE STATE OF THE S	The Control of the Co	n 855a	garbanitu si (an L.J. 1973). Nagar sang sang Magazar		P3500	10141	- 5 449	-109	5000		1293	1048	255
Service of the servic		The state of the s	direction and managementalism in the last state of their commentation in the state of the state	mel Brooks erencement of the control	Commission of the second	pendantanar kanuah danar 1 m mai ai pena ur fina suda.	e materiale de la companya del companya de la companya de la companya del companya de la company		+2000	11.562	-5128		00033	1506	1231	1037	194
2301		4856	. Boy	reduce of the control	· · · · · · · · · · · · · · · · · · ·	TELEFORE 14 F T T T T T T T T T T T T T T T T T T	Processing 1 to 1986, part was farechipping a	A manager co. The specialist manager co. In the special speci	450C	6657	-5014	301	20500	1197	1268	1087	81
1608	8576	3311	de la companya de la La companya de la companya de	S. The Age of	668	26/3	en e	e i Martinaceur y see engas es	1000	1806	-266	16	10500	1170	1266	1085	
1278	8660	329;	4319	2721	148	2573	(in White-11) al White-color coloradore triple) James Strawing	And the desired of Andrew of the State of th	+ 500	1496	-670	- 4×	10500	1118	1264	1085	179
1689	Carlo Andreas Carlos Ca	3572	5261	3429	100 mm and	5429	gadinan a mandid ph. 1 - 1000 p sa sa taman singa a g s i	er of state awar promise soular t	11500	3332	-67	age of the	10500	2104	1263	1085	178
1947	J. 15 26 5	5520	7:37	5043	nga makasakan anakasakan kalan makara bahang Tanbaga	5049	STREET		+500	1899	-600	-37	13000	1053	1261	1055	176
1734	5800	2263	The second secon	1726	A CONTRACTOR OF THE PROPERTY O	1726	22!2	, and the state of the second	The state of the s	TO BANK THE STATE OF THE STATE	+675	1.40	15000	1079	126%	1085	177
3395	7552	2010	6265	5611	Special programs, de 1979 (a. s.). supplementario de 1 e actividados	56 <i>1</i> 1	453	S STATE OF S	- 500	1268	-322	- 20	15000	3044	1260	1005	275
6014	15126	8017	12091	1296	and the second s	7294	1367	Total of the community	-800	3930	+ 250	+ 5	5000	1044	1260	1085	175
4700	15398	11935	16635	10241	C SECTION	10241	2033		1-100	4861	+250	+5	5000	1044	1260	1086	1/4
8200	15398	12542	17742	1895	A System	8896	2417	E ase.	The second second second	7269	+ 349	+7	5000	1046	1260	1087	173
Parallegiseerinaans voir 2514 era tiiraankoolur 1754aaa s C	8859	gad vers) – v ragiji, u ze v i itominimus krajektinamin, de gad St. mil majde	ing paggaban panggan anggan panggan 12 manggan 12 manggan panggan pang	rangungangan namu. dan kupungan s	C 051	2.776 dates. Justice, a sea processive recommendation of commendations of the commendation of the com	1.44-9	migration of the second of the	702.2	en, aggaggaraporeuryden, yf rifed i'r higysfeyntarannadd		, , , , , , , , , , , , , , , , , , ,	0.093	and the same of the same and about the same	And the second con-	and the second	

cs = cusecs MAF = Million Acre Feet

m Penstock (f+)	Net head (ft.)	Mean (ft.)	Efficency (e);	Power IN M.W. Q.H.c/11800	Period
<i>3</i> 5	36	37	38	39	40
		and the state of t	personal proper of comments and	Programmed	manufacture (in the contract of the contract o
10	191	1790	0.83	122	July
io ,	200	195.5	0.84	135	Aug
10	200	200.0	0.85	150	Sept. 1-10
8	202	2010	0 05	124	11-20
		1000	00-		
10	195	1985	0.85	145	Sept 21-30
8	186	1905	0.84	114	Oct.
6	175	180.5	0.83	85	Nov.
6	175	1750	0.82	22	Dec
6	173	174.0	0.82	18	Jan.
6	172	172.5	0.81	16	Feb.
6	170	1710	0.81	22	Mar.
6	171	170.5	0.81		APn
Angeliage facility of the great Config.		4.51.6			
6	169	170.0	0.81	15	May.
6	169	169.0	0.81	46	June1-10
6	168	168.5	0.81	56	11-20
6	167	167.5	0.81	84	21-30
Manager Manager & Manager					MAF

COURSE.	Ð.	28	100	* *	ACCOUNTS.		
Sand Sand	*	-3	A	1	1	A	
	T.	7	And a	1	Samuel .		
المتعاقبة لايا	0	ø	ø. 🐞	3 4	£ #		

Perios	MFlow in River Sullej ar Bhakra (25)	Supplies divisited three to 500 c. s. of (Sheet 10F1)	Total inflowed (5) Bhakra (5) (col. 2 + (4) 3)	Requirements of Rejasthan Canals at Rupar	Swolies deliveredto Rej Canals after applying Re Fector diring de pleto Period © 38% CCS	Dathi drimking Water Subblying (CS)	of Punjab cames at Rupar (CS)	Supplies delivered to Pb. Canals after applying Res. factor during depletion	Total Supplies delivered Purjab Canals at Rupay (CS) (COI 6+ COI 7+ COI.9)	Contribution from Jamuna (CS)	Gain or 1055 between Bhakra and Rupar (CS)	Releases made at Bhakra for Rupar Canals {Col.10-(Col 14+Col.12)}	Supplies released at shakke canals (CS)	Releases inthe interest of Power (cs)	Total releases made at 8 hax ra (Q) (Cd.13+Col.14+Col.15)
1	2	3	4	5	6	7	8	9	10	11	12	/3	14	15	16
				4.								8		mentiff hip in the same of a sunday in agricultural habit as in the same of th	
JULY	37430	7500	44930	420	420	325	22493	22493	23238	2067	+1000	20171	***************************************	Ministración de electronica de elect	20171
AUG.	36658	7500	44158	420	420		22493	22493	23238			18643	- Contract C	Antidon aglant Annocono con constructivo de contrato e anticopo e muna Climano	18643
SEP. 1-10	24305	7500	31805	540	432	325	26355	21084	<u> </u>	1615		19901	6453	Nagrico de Caracine de Caracin	2635
11.20	14661	7500	22161	540	205	325	26355	13177	13707	425	-	13707	-		1370
SEP. 21-30	11301	6326	17627	540	205	325	26355	13/77	13707			13707		parts	1370
ост.	6513	4450	10963	480	182	325	26624		13819	-	_	13819		negatura est en en esta esta esta esta esta esta esta esta	1381
NOV.	4597	3113	7710	480	182	ļ	24043	12021	12528		_	1.2538		Chrystolechine von Christolechine (Christolechine) (Chris	1253
DEC.	3808	2175	5983	_	128	325	16421	8210		-	+ 100	8563	3341	1540	1344
														Agricultural (Agricultural) (Agricul	
JAN.	3272	1796	5068	270	103	325	13261	6630	7058	-	+ 200	6858	2721	5881	1546
FEB.	2980	1928	4908	366	139	325	17708	8854	9318	-	+ 400	8918	3429	4165	1651
MAR-	3345	2809	6/54	420	160	325	20056	10028	10513	- 1	+ 200	10313	5048	Cha	1536
APR.	4683	3519	8202	300	114	325	13088	6544	6983	- 1	- 300	7283	1726	6520	1552
												·			
	10409	7/44	17553	480	182		26068			-	- 600	14141	5611		1975
	-	7500	23654		182	ļ	26499	13250			- 600	14357	7294	•	2/65
11-20	18566	7500	26066		480		26499		16705		- 600	17305	10241		275
			36800	480	480			26499	273 04	State of the State	- 600	27904	8896		368
The state of the s	9.299	3.6//	12.910	0.304		1	15.533		1	0.384	0.086			1.08	
		Mathematic	1	1		1		1							

Withdrawal in Cusecs (Col. 4 - Col. 16)	Storage of with drawa!	Losses in Reservoir (acre feet)	Net Storage in T.A.E.	Reservar Elevation (ft)	Tailrace Elevation *(ft)		Mean Head (Ft) (H)	(Col. 24-4)	Efficiency (e)	Power in M.M. at Bhakra 8.4.e/11800	Power at Denar Power Plant (GOLIZOF Sheet 1011) (M.M.)	Power or Pong Power Mont (Col 39 of Sheet fort) (M.W)	Power at Nangal Canal Power Houses (M.W)	28.2	Periad
. 17	18	19	20	21	22	23	24	25	26	27	28	29	30	3/	32
			1699	1462											6.2
24759	+ 1532	10000	3221	1550	1174		332.0	328.0	0.82	452	530	122		1258	july
25515	+1580	10000	4791	1612	1173	*	408.0	404.0	0.84	535	530	135		1354	Aug-
5451	+ 109	4000	4896	1615	1176		437.5	433.5	0.85	825	530	150		1659	Sept. 1-10
8454	+ 169	3000	5062	1621	1171		447.0	443.0	0.85	439	530	124		1247	11-20
						¥.									
3920	+ 78	3000	5/37	1623	117/	4	451.0	447.0	0.85	443	455	145		1197	Sept 21-30
2856	- 177	8000	4952	1617	1.171		449.0	445.0	0.85	444	327	114		1039	od:
4828	- 290	6000	4656	1607	1171		441.0	437.0	0.85	396	230	85		865	NOV.
7461	- 463	6000	4187	1590	1171		427.5	423.5	0.85	411	161	22		748	Dec.
										10 10 10 10 10 10 10 10 10 10 10 10 10 1				大块	
10392	- 644	6000	3537	1564	1172		405.0	401.0	0.84	443	133	1-8		748	Jan.
11604	- 650	6000	2881	1534	1172		377.0	373.0	0.83	435	143	16	4	748	Feb.
9307	- 577	8000	2295	1503	1172		346.5	342.5	0.82	367	208	22	, ,	751	Mar.
7327	- 440	10000	1846	1473	1172		316.0	312.0	0.81	334	260			748	APY.
													nic III		in a second of the second of t
2199	136	10000	1700	1462	1174		293.5	289.5	0.80	3.91	509	15		1069	May
2003	+ 40	4000	1736	1465	1174		291.0	287.0	0.80	423	530	46		The second secon	June 1-10
- 1480	- 30	3000	1703	1462	1176		286.0	282.0	0.80	528	530	58		1268	11-20
		3000	1700	1462	1179		183.0	279.0	0.80	698	530	84	V	1466	21.30
														- 0	
						- 4									

M.A.F. = Millon Acre Peet.

TA.F. = Thousand Acre Feet.

K		of the enterpolitical in 1980-1988, or consultable participation or 17 paragraphs (1971).	file in Address — school Michigan Williams of Address — school	DEHAR	POWER	PLANT	gli.	no i Magair i Rhadh i di ac i se uno i mo i dhuasan	ender Endly-köllerböllerkatenderschler _{kalle} k, yherkayste sian	alinantestoyetha" a to dang make against against	*		mand P a summandare of the beginning of the control to the selection of th	d with a grade of the stage of	erstennistennistennistenniste de Nagyt-Valdeten intaksistensistensistensis
PER OD	BEAS AT PANDON FOR DIVERSION	SUPPLY SIVERTED THROUGH B.S.L. LIMITED TO 7500 C.S'Q'	ELEVATION (ft)	CROSS HEAD AVAILABLE (2760 - COL. 4) (ft)	HEAD LOSS IN TUNNEL 0.762 x 10 6 x 0.2 (ft)	IN PEN STOCK	TOTAL HEAD LOSS (#t)	HEAR CO	CAN HEAL (FT) THE COESAVERAGE TAN PACE DEVATION	FEE CHENCY	POWERIN M.W.	AT PONG	SUPPLY DIVERTED TO 3.5AS IN COL. 3 (CS)	AT PANDOH AT PANDOH (JOURS - COURS)	CARAUS AT HARRE (CS)
	The second secon	2	Mary Mary	5	5	Andrew Control of the	8	9	10	A Company of the Comp	12	The state of the s	(4	15	:6
000V AU23 588 0[-10	20087 21038 (4920 (1)60	7600 71.00	(650 -550 -:650 :554	1110 1110	4.3		68 : 3 5 8	10 42 10 42	C42 C42 IC42		53C 530 : 30	3004 50224 21840	7500 7500 7500	2344+ +2724 24340	7/ 0 7 2007 1154
5EP 21-30	rmilajujuk kampulitin, ukukalindipi kajumi, ir 1944 prijukske po curra d ormilaju – putrajuktinaju 110 % ar 11 44 45 45 45 45 45 45 45 45 45 45 45 45	7500	1655	1105	43	25	68	1037	(037		527	:3926	7500	6.126	7:54
OCT.	5040 2667	5040 2557	1650 1650	1110	5	15	37 20	1073	107C · 5	mag a lawa i a mada mada mada mada a a a a a a a a a	366 197	8055 4743	5040 2657	3015 2076	4602
DEC	2111	P P P P P P P P P P	1650	(110	3	15	18	1092	1005.		57	4108	2111	OST	3217
- AN FSB MAR	1912 1956 2930	1912	1650 1650	1110	3 7	15	8 2 2	1092	1092 1098	C.8	1.12	3939 4133 5065	1912 1956 29 3 0	2027	2557 3379 3835
Fig. \$7.		5194	1650	0	2	18	30	1971	1971		379	5837	5199	1638	3469
To va V	7564	7500	:650	11-10	A 3		68	1042	1042		530	9326	7500	1826	6790
JUHEF-110	9333	7500 7500	1650	1110	4 3	2 5 2 5	68 68	1042	1042		5 3 0	10122	7500	2622	6790
2!+30	13866	7500	650	1110	4 3	2.5	6 8	1 042	1042	11	530	15 363	500	A STATE OF THE PARTY OF THE PAR	6700
MAF	5 .77	3,62						ander en ser en				9.97	The second of the professional and a second	6 35	3 6 8

	į	VEH	BEAS
free?	1	1 2 2 3	

2	The commence of the part of the same	Annual Control of the	engerment of the second participation of the second partic	A Management of the state of th	Manager and Assessed	graffiance assessment or	tyru are between compa	*	Tol Sugar 1 - Appropriate Sugar Suga	man i samuela i sa samuela de la seconomica de la seconom	MORNING DEBLAT VAT 1	g a 'como - promobilismostranianos - sa					:
PUNAR ANAS F HA R AFTER APPLYTOR R.F. DURI	SECURING NTS OF RALASTH	TANK TO THE SAME THE		HAPPING CANALS		AT HARTE FROM HIAME	THE STATE OF THE S	INITAL STOP POWER	GANG BUSS OF PLAN	COLLADATE ALENSES AT	DHAMALIN CUSICS	STONAGE OF WITH	PUSERVOIR IN ACRE FEE	PONG RESERVOIR	RESERT OR ELEVATION	TAILKHLE TENTION	GROSS HEAD FT JOL,32 - COL 33
	8		20		22	,	24			- Ly	ng.	5.6	30	3.	3	3	The state of the s
			***	The second of th	mercon control	Amman (Amman Amman	Shariful time in the state of t			Mengen Marinde Corrier (and Perfect Representation Corrier (and Corrie	All minimization is account inflation of the minimization of the m		Section (1) Sectio	The second secon	And the second s	The second secon	Programme of the control of the cont
017	114	*	a i		A APE CONTRACT	Annual	300	- 1 minutes .	* : 0	547	35" 9	+8.6	5000	7.5	1297	68	27.5
	A Carlos San Carlos Sa		** ** ** ** ** ** ** ** ** ** ** ** **	e e passion :	gyrin wentri iransaa	Spyride s r , service state of the state of	5 00	er haddissoriu ladgebys, r	1.500	A A T	3302"	+ 2051	15.000	3800	13213		255
Andreas and the second	and the second	A COLUMN TO THE STATE OF THE ST	z skis	ernanna i se i haa	parties of	engantantantantan e menteng tempogramian	24:	Approximations Adjust solventry (* Topologia page)	And the second	The statement of the st	Serge of a	+12	50.00		1345	108	264
A CONTRACTOR OF THE PARTY OF TH	TAMES TO STATE OF THE STATE OF	the second of th	The state of the s	Action	-	see to the second of the secon	Wint () veranda S S S S S S S S S S S S S S S S S S S	and the second second second second		1446		10	Andrews Company and Company of the C	The second of th	1.544	1000	esta. Surganistratos (5%) condido, maginos sura sura
	come and and come	francis de la	ا موسد می موسد ماهی بر بر موسد	E i vAn .	2 Samester of American	BBSSBS \$4 nated (settlem to 1 settlembers)	na referenciationes - 1/2 apriliagizationes	· /	Parties Balletin Balletin Balletin College	on-cest. A. San Talabasanga h. / citamatangan walikkit Ving	puls-prophydiaes (gets committeelementation (*) Allementation (*)	and the second promotion to grow an incidence of the second	eritation terminase - con unempionimeteria, c out un la projection	2 17 ordere op 1 Streaminnsonsganjert i des geld i	American Company of the September of the	o e e e e e e e e e e e e e e e e e e e
tCol	2122	135-4	13615	us sittem as L _{es} sammes a l estamble e e	-	engagee PPFF TEV gentarios s	magain i mbabb	apre :	~ I5C ?	in the telephones are a contradition. The	10709	TOTAL STREET,	5000	37.11	1540	100	249
32	8582	11 18 1	15 (0)			Bushman i .	Sharp What Maring Maring	Affic Mic de Angleige.	+1000	4197	-11185	693	13500	3004	1325	1090	235
329	1278	821	proces activements of annex of	der mannengen (der ermense errang generem men in ar en er er er	y racens	- verskedviljeskom; - versked	доск (с. 1920-година) Виническия Г. А. 1. 100 година (придадина предоставления при стория)	enery ,	500	1 965	8590	533	10500	2460	1313	1088	225
220	3810 ·	5703	79.73	3341	558	2673	a Statementer	1994a tyanga ant zidakajastehiro-kansangka Pro-	500	4800	- 2803	174	10500	2276	1308	1086	222
1805	8550	55528	7373	2 2 2 2 1	148	2073	Springer (1757-1844) i Augustanian e propriator in term	er vik i fi i i i i i i i i i i i i i i i i	+500	4800	2773	-172	10500	2003	13 04	1086	2:8
2385	0400	0044	8429	3129	de serraman de ser e estado de la compansa de la co	3 2 3	I constitutive to a seaso - Spattagenesis on a season - Sp	AMAGE - City as	+500	4800	2623	-147	105C0	1936	1300	1086	214
2708	14525	9340	12048	3048	}	3048	Ages system interest the section of	To disease hits.	+500	gill he encommonately a the unidelynamical in	-6365	395	13000	1528	287	1087	200
2449	5800	3 729	6178	2831	der sterat salas sensites del riguarinyo	2 831	2212	and a supplier and the control of th	And tyles	1135	+503	+30	15000	1543	1288	085	203
			professional control appropriate approach of the appropriate and the appropriate appropria			gett, dir. j. ir gov. p. ir. actifelik ir. Meniestaddaan inhah	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	A services sentendentifica		Andread Berger 21.0 terriporti della constitución de 190 d	Company of April Open September	And the second s					
4794	7552	48 55	9650	Principal and principal appropriate and the control of the control	Tulbito-turbanetuppos	processors and characteristics of the second	4 5 3	manus o como a demos ago seño sida de de de comolomos se co p.	500	96 9 7	7871	488	, 500 0	1040	1264	1088	176
1794	51.26	9726	1 4 520	6:53	Andreas of the state of the sta	prompted the control of the control of	1367	Total year of the state of the	500	1500	- 4878		5 000	938	1260	1087	7 3
4 % 95	153.98	The second secon	To the second	005	nger in problem - communitary / ng	1325	\$ 50 0 35	And the state of t	500	5481	+ 250	1 + 5	5000	950	12 60	1086	174
5 34	15328	3300	2334	2 2 4	обоски и меженового поверени до поста обоснования по поста обоснования по поста обоснования и поста обосн	3744	477	Security of the security of th	- 500	76 13	+ 250	+ 5	5000	9 5 0	12 6 0	1087	173
Mary treat		Company of the second s	THE THROUGH THE STREET	dig	10 O =	Commonwealerser inchesser (5 n. 5 n. 5 n. 5 haven) (The state of the	E and patentings on major	+-11.428	mer i upuntertat magnatu urafandat kaji tengua pandigi e pame () pan e antigua.	urrigens; hyd celebilibushaa epimalailyinapus pahaa byseyna, u	angungsi ng igangkan ing mangkalan man a dan ing	Too a s				
gara.	8,85,8			1	0.051	1	, and the state of	<u> </u>	affect to the second		1			And the state of t	والمراجع والمتعادية والمتعادية والمتعادية والمتعادية والمتعادة والمتعادية وال	ne privo de como composições de propies que	Anneal or the separate property

		Section 2 de constitue de const	F1 + Medic No.	garan ang mga ng	
LOSSES INSENSTOCK	NE HEAD	MEAN HEAD (FT.)	FFICIENT Y	POWER IN M.W	The state of the s
35	1 35	7 / Cabana and a second and a s	3.5	19	
	of the company of the		manufacture manufacture to the state of the		before the first and the first
0	99	82.5	0 83	123	1011
+ 10	245	1225	0 85	153	403.
P.	244	24.4.5	0.84	315	\$ 527 T 1 150
	244	24410	ା. ୫	251	
мантарта (т. т.р. админараца г. ц.)	and an alter Assessment of the	and a productive special speci		The second secon	
10	239	241-5	0.84	297	21-30
10	225	232	0.84	234	OCT
10	215	22C	0.85	173	NOV
6	216	2155	0.85	7 5	DEC.
The second of party arrange.					E (MAG) ji
5	212	214	085	74	MAL
C	208	210	0.85	73	FAB
8	192	200	0.8 5	12 3	MAR
6	197	94.5	0.84) ô	APR
an in Assault and the State of			Anne de constitue de la consti		A TOTAL THE SERVICE AND A SERV
10	166	81.5	0.8 3	124	112
6	16 7	: 67	0.8 (3.6	JUN AO
6	168	168	0.8	64	11-20
7	166	167	0.8	87	230
-0 -FLETON ALIBERTAN		Management of the party of the			
		1 Hans			
,		The state of the s		(M. Pro	56884

A 56884

	A	inger to the second of the sec	Proc. 201 and Adul Serve Statement of the Space Serve Space	interpretation automobilisment of principal $x \in \mathbb{R}^n$	in and the second designed	employees in the tells, of a symmethy	The instance of the second state of the second second second	nde place — agrammatassaman is no prigate angestarior bisassis men ar	BHAK	(RA-	Ching Anth-Allending Priville I and Anna I and Andrews	rangami salasa — arabahki etrik disener philamenyak ke i z — etri f A. s	ong in the control of	rys, american por vice some	Sandan
PERIOD	SUTLE JATBHAKRA (CS)	SUPPLIES DIVERTED THROUGH B.S.LLIMTED TO 7500CS(COL 3 OF SHEE: 1 OF	TOTAL INFLOW AT BHAKRA (COLZ+COL3)	REQUIREMENTS OF RAJASTHAN CANALS AT RUPAR (CS)	SUP PLIES DELIVERED AT RAJ. CANALS AFTER APPLYING RES. FACTOR DURING DEPLETION PERIOD (6.4.3)(CS)	SUPPLY SUPPLY	TOTAL REQUIREMENTS OF PUNJAB CANALS AT RUPAR (CS)	SUPPLIES DELIVERED TO PB.CANALS AFTER APPLYING RES.FACTOR DURING DEPLETION PERIOD @70 6(CS)	TOTAL SUPPLIES DELIVERED TO BOTH PASASTHAN AND PUNSAB CANALS AT PUPAR (CS)	CONTRIBUTION ROM JAMUNA	GAIN OR LOSS BETWEEN BHAKRA AND RUPAR (CS)	RELEASES MADE AT BHAKRA FOR RUPAR CANALS [COL. 10-(COL. 11.1 COL. 12)]	SUPPLIES RELEASED AT BHAKRA FOR HARINE CANALS (C 9)	RELEASES IN THE INTEREST OF POWER (CS)	MADE AT SHAKAA
1	2	3	4	5	6	7	8	* 9	10	manusche ausgebergen ist versche der von der versche d	12	. I	£.	15	.6
	jaminys ilyko-daetiau sijaddys tid manyagianen jahaadayiniga samai ya Manyaddan 6 ulikungi Cingiy malaa adalbudan ibini Milion 7 ata, 4 1 mmm								AND THE PARTY OF T	us officere of the second seco	ger van Schaffe der Schaffe oppositieren van van der Schaffe der Schaffe van der Schaffe der Schaffe van der S Generalisation von der Generalisation von der Schaffe van der Schaffe van der Schaffe van der Schaffe van der S	Control Control and Control	new of positionalise and the property waterdenance		
JULY'	43557	7500	5!057	420	420	325	22493	22493	23238	2067	+:000	20.7:		And the state of t	: 0171
AUG.	45694	7500	53194	420	120	0.25	28493	The state of the s	23238	3595	1.1000	127 13	Se rigadism main	one control of the co	18:543;
SEPT.1-10	28997	7500	36497	540	54C	123	26355	26355	2/220	1615			2 man of the second sec	manus v. Labour paramete.	25005
11-20	20559 anno a managamenta da managamenta	7567	2.8056	540	347	325	26355	1850 7	19279	State of the state	The state of the s	TO A STATE OF THE PROPERTY OF	processor (see a second control of the secon	унарадияння стран с так на при	19675
SEPT.21-30	12930	7500	20430	540	347	023	26355	18607	19279	A r		19279	mentalentalentalentalentalentalentalental	Specification (Control of Control	19279
ост.	8259	5040	13299	480	30.9	325,	26624	18797	19431	- Ag selection of the s	Marie of the second sec	1943!	American (n. indistribution) - I commente (n. indistribution) - I commen	Management of the	1543
iov.	5432	2667	8099	480	309	325	24043	16974	17608	a a region de magnetica de la composición del composición de la composición de la composición del composición de la composición del composición de la composición de la composición del compos	But any part of the second sec	608	Service Control of the Control of th	Annual Control of the	175.08
DEC.	4339	2111	6450	336	2:6	325	16421	:1595	12:36	ependigues y commune, franche internative commune de la co	+ 150 0	12/36	334	The second secon	
J'A N	3864	1912	5776	2.70	174	323	13261	3362	\$861	Appel rest succession. Supply all set sets.	1200	73 6 6	Agency Control of Control	A CONTRACTOR OF THE CONTRACTOR	
FEB.	384	1956	5797	366	235	325	17768	1.2502	13062	and the same state of	And the second s				
AR.	-43 8 2	2930	7312			123	20056	1415	14755	gram gram transcript or an ambition of the contract of the con		And the control of th	The second secon	The state of the s	market and a second of the second of
APR.	£ 7.4	5.99	10:040	300	153		1 7 8 8	The state of the s	1000	Man of the state o	and the second of the second o	proc. Baselineaeconomic a communicación y autoria sentidorien	And the second second	CONTRACTOR OF THE CONTRACTOR O	
M A.S.	11100	7500	18600	Andrew to the second of the se	A Company	1 325	26088	18454	9038	Section 1997 And 1997	1-600	19638	And the second s	agreement of	19638
UNE.I-10	18516	7500	260:6	480	309	325	26499	,8708	19342	Company of the compan	600	19342	6153	p. m.	2609
nt an 1977 johny hannyarittissiskistatatationede op generaliskister-verb (249 85	7500	32485	480	480	325	26499	20859	21644	The control of the second control on desired	-600	22244	:OD91	Transport of the Control of the Cont	
21-30	30298	7500	37798	480	480	325	26499	26499	27304	ugi nagga ya yan kanasa wunda na Amaka ma Mala Ama A A A A	-60.0	27904	9744	general registes () a registration and it is a series of a registration of a redistration of a series and a s	37648
M.A.F	11.125	3.62	14.74	0.304	0.225	5237	TIS 633	The State consequents and report the second state of the second of the s	ereit, men samp frage is foreignstellige in digen. Australian eine son ein ein ein ein ein ein ein ein ein ei	0.384	0.086	12:130	menementalisen japan periode kantakan periode japan jabah ja	1.099	
golianitari/maunitra-rannu-vin-sunnakyulik-rintstri - ri	State of the state	Behand dig is Transport own on Indicators in the Company of Indicators o	н өңийдект данартыр 2-тары Эрө, уларындары «Бей» түй түй түүлүү арады дануындарындарында организмерен түй кайтайын байындары байындарын өнөр Дануындарындарында организмерен түй байын байындарын байындарын өнөр	ar an der geren der der geste d Geste der geste der	The second section of the second section of the second section of the second section of the sect	T Agentia cure supresi (attradessa intra desprimentamente	подава <mark>принципалнично протис</mark> но на поста и вода Д ченова подачения		The state of the s	THE PROPERTY OF THE PROPERTY O			SERVICE TO THE PROPERTY OF THE		

WITHDRAWAL IN LUSERS	STORAGE OR WITHOUR WAY	RESERVOIR (ACRE FEET)	N N E E	RESERVOIR ELEVATION (FEET)	TAILRACE ELEVATION (FEET)	GROSS HEAD	NET HEAD (84)	ME. HEAD (FA.)	EFFICIENCY (E)	POWER IN MIN AT BHAKRA QHE / 11800	POWER AT DEHAR POWER PLANT(COL.12 OF SHEET 1 OF ST	POWER AT PONG POWER PLANT (CCS 39 OF SHEET (M.W.)	POWER AT NANGAL CANAL POWER HOUSES (M.W)	TOTAL	PERIOD
COME CONTRACTOR AND C	. 8	19	20	21	3 6	23	24	25	25	27	7. 8	The second secon	30	31	32
and the second of the second of the second	Control of the second of the s	The second secon		Strang Drivi - Ser of Great water attributions over your materials from the expressions - Let to serie e.g. (i)	matemates i sept and for to got greater () in the State of the property of the great of the great of the greatest of the grea	The state of the s		particular to the second of th	。 いこ。proproproproproproproproproproproproprop	Andrews (Andrews Comment) of the Andrews (Andrews Comme	The second secon	enterente per l'option de transcription de l'activité de l	Household in Manager in a Franchischer Mathematich (1994), control of the control	ing a hang again gang pagagan ang ang ang ang ang ang ang ang a	And the state of t
706	1.9:4932	-0000	3875.43/	£ 6 3	1170	393	1:81		(° %)	-71	The state of the s	merano, y pyromittan e nadasi, i se in		278	JULY
The section of the se	1-2102-60	15000	500194	1639	1170	4:0	*	107	C 85	The second secon	4 		and an article of the second s	1.4 11	AUG.
a state of the state of the	1 217840	The second secon	6222434	1645	1172	4.73		157	084		ege mouse southwater en ee	100 may 2000 may 200	u erag aragarinafar urru ianir a ing	1651	SEPT 1-10
- 8 40	The state the the state of the	3077	6333034	1649	1170	470	The second secon	The same and the s	0.84		Section of the sectio	Agriculture and the second sec		The statement will be acceptable to appear to the statement beginning to th	11-20
2. 1	1+530 500	300C	54:505.4	Control Control of State State State Control	managan saga sagays, asa				Assistan service - was even		The state of the s	The second secon	a de la companya de l	e de la la la la la description de la	Principal and antique and approximate the second of the se
6.32	ng distribution of the second	8000	18021870	165 6 :639	1170	480	476	4 3 7		The Specific Section 1997 to the	366	The second secon	per process as , or charging the r at a 11 f as a control of	16.1.1	SEPT.21-30
9509	£ 570 p.40	gar et sometalmisteri i se sisperendi baseren eranen e e ege	5450330		manatalistica, risolarinana apalakusus na inces		447	4705	2.84		197	.73		1095	NOV.
-10500	-65100 c	mantanistation of the control of the	4703330	1599	1170	451	426	436 5		534	1 2 4 1 5 1 5 1 5 1 5 1 5 1 5 1 5 1 5 1 5 1	er e	And the state of t	020	DEC.
g in D. Aguil North Law (1990)	Andrew Street Management - Littler - and 1950-1957 streets repair	Application of the control of the co	The second secon	The Additional Constitution of the Constitutio	1. 3			4555	econ are never a	A COLUMN TON	The second of th	B Rest			Surp - Greek - Nagar
	7.5088	667.5	3.002248	15-1	and the party	7.2	300	40	C 85	550	1132	***************************************	The second second	9:0	JAN.
The second of th	The second second second second	+000	5.7.5.4	1330	The second secon	the the second second second second	234	3.75	10,54	4 12	The second secon	gen an hydrogen responses of in the segmental controlled the segment of the segme	TORCH	920	FEB
-1 3F &	The state of the s	8000	The result private our our receives many	1191	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	3 4	A A A	A To See	and the second s	1 45.		age for any taken any a participation		920	MAR
The contraction of the contracti	The state of the s		man agen		1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Control Control Control (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	234	The second secon	C 3,	1 372	3 8	Acceptance of the second of th		920	APR.
and and an extreme	A 12 July 20		10000		And the second s	e i we widospa ii gistanda	entremetations (Part Serie page	Tomore constructe (Campin) with	and the second s	-	and the second s				A R C NA
The second second second	The Hotel	100.00	1504108	draw in water was a mount of a			1:81	23.5	080	388	530	124	S AND	1275	JUNE 1-10
	1+3000	3000	1987522	j gg(* - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	The first of the second of the	o come come or co	285	2875	7.80	509	530	8.6	The second second		and the second second second
nto i e kir grajaje i toj grajaje kajajeno i i denate	rofer inchespie i care continuosement e income e i	ing provide a complete in a security of the section of the	The second of the selections of the second o			285	282	284	A STATE OF THE PARTY OF THE PAR	1620	5.30	54	MET TOMOTO - MARKET METHOD		11-20
to 1500	3000	3000	1971500	1462	1.75	San	283	2 2 3 5	0.80		STORES	F 3	1 - 4	and the second s	21-35
	1		- Company	and					-		3	1	****		

T.A.F - THOUSAND ACRE FEET

Sheet 242

G mayor in this to the particular management and the particular and th	Space of the second sec	ers fin dame : ; ; ri ; e : designation dess de lamba assignativi : ; e la legi-	-DEHAR	POWER A	LANT	and some strangers of proper states agreement	Makes and Park 11 March 11 Mar	iki NCD - 1170d - k Tulich Nillen Olikusalasan kalijasi ka	hafted scale by integrational and the p	ME Committee makingan, ita abir ii ii	na (malitala) (Malital	and the state of t	a gradinate white the soft the Atlantice	Mildellegiller Jogus standarderungen vir steer	974 * 1877 98864 S ERSON - 1887 NEC - 1887
Period	Beas at Pundohi for chirevsion to 8.56 (CS)	diverted through B.S.L. Innited to 170000 C.S.	Failrace Lic vation (+1)	Gross head avadable (Grev Col 4.) (1.1)	16 ad 1655 m tunnet 0762×106×624	He col 1055 m Penslock (11)	head 1055	Net head (ft) (CUS-068)	Mean head (ft) 2760 Colle-average talling Lievation	KHILIKTCY 'C'	POW TRIM W Q H C HOUD	Inflow of Rices at Pong (cs)	Supply diverted to E. as in col 3 (cs)	Acas at Porgatic	Requirements or Punjair Canals at Harike
	2	3	4	5	6	7		The second beauty to the second to	10		12	/3	14	15	16
THE PART OF THE PA	:				111	Anthonymentoning and the second of the secon	enterprise agent challenge in a granter of the challenge	Cashinare de 179 au gant matrich i 178	A Chichester	The second secon	eres promised and ancientes - a singular con-		a Vindentina & Landandellini - Landandellini - Graphylligi (1921-1928)	The additional of assembly direct paths of the page of	a vanada da la la consideració la especía de la consideración de
A Commence of the Commence of	2234:	7500	1650	1110	43	2 5	68	1042	1042	4	530	40202	7500	32702	700
Aug to St	24400	7500	1675	1085	43	25:	68	1017	1030		523	62120	7500	54620	7007
5-pt 1-10		7500	1684	01c1	43	25	68	1008	1013		515	45862	7500	38362	7 54
11.20	14081	7500	1687	1073	43	25	68	1005	007	ectivit elabora i da social laboratione	512	32845	7 500	25345	7 154
	Ballichert on Land - Highwigh - Stadichel in Edit unblikenwein im E	promotives were britished the regions obtained and the or to a so manifest	Militaring management and an array of the second se	makkin wananan in 17 njiyan anda ya ya ya wa	n der i ha i ha arsanne		· · · · · · · · · · · · · · · · · · ·	t see and	troffellikuskupet r. t		Managaman I Ad months	d.	anne dept kanton il en il sind as la hudelettan delimatera	و مرد المناف المناف المناف المناف المناف	nagah /augh) yanununka eganya .
Sept. 150	entranse i e remani e respectivo de la compania del compania del compania de la compania del la compania de la compania del la compania de la	7500	8861	1072	43	25	68	1004	1005		511	22345	7500	14845	7 54
e George Consequence (Consequence (Consequence (Consequence (Consequence (Consequence (Consequence (Consequence Consequence (Consequence (Consequenc	84 54	\$ 4 54	1673	1087	32	22	54	1033	1019	1	449	13049	6454	6595	4602
Dec.	2259	3077	1050	1)) ()	7	15	22	088	1051	0.8	225	5831	3077	2754	460.
and the second s	Times the second of the second	pare All Sept Set), had had had been been been been been been been bee	1110	and a second	15		1091	1091	tus vides purces a see observed	157	4851	2259	2592	3217
han.	All Car and the	2030	1650	1110		15		1092	1002		151	507.7	2039	3038	2557
FPB.	22 5 9	2250	1650	1110	4	15		1091	1001		167	5774	2259	35 5	3379
Mar:	3402	3402	1650	1110	9	15	24	1086	1086		250	6588	3402	3286	3835
Apr	5671	5671	650	110	25	20	45	1065	1055	100000	410	8496	5671	2825	3459
May	8852	7500	1650	1110	43	25	68	1042	1042		530	0934	7500	3434	679
June/10	11344	7500	1650	1110	43	25	68	1042	1042	r ramonari 1. H	530	13330	7500	5830	and the second of the second o
11-20	12928	7500	1650	1110	43	25	68	1042	1042		530	14774	7500	7274	679
21-30	16081	7500	1650	1110	43	25	68	1042	1042	+	530	9015	7500	11 515	1 to tempoperate .
1.A.F.	6.65	3 . 823	manuscripturas and a second se	management of the content of the con	any programme and the control of the	and the second s	Michigan Indiana (American y Age ()	Annual Section of the Control of the		The second secon		13.008	The procedure of the second se	9.185	
	States and the state of the sta	The state of the s			- Company					79.	-			erande de la companya	profitation of antiques of ant

	and charteless for	RIVE	F BEAS	griff contribution is	t barn, spr. it /middesembers, /	s bettern i i	Tigo State of High States	as pre papeapratur tau bernite i vi	is in the specific participate.	mysis (*) - regisk skulpture (*) Jakoburgelaus, geograf (*)	ente el tito complete la mangellación (15° qualità l'immerga el es manife	Militar comments and the appealance of a second	Agus and a second section of	and a constant of the constant of the section of th			g - gya kigat a wine - 1 - 1
	Canals at Hank	Ray Canals at Hark 41 Canals at Hark THEY GED IVING R F TUNING DEPLETION AN OCA AT 160 % (C.)	Total Supt 17 to Punjab & Kay. Canals at Hoorke (contracting (CS)	Rekoses madeut Shukid Madeut Harike muss (CS)	Shakred Harree	Net surplies deliveral at havike from Shavialis 21-60	Net Supply available through M B. Link at Havine (CS.)	Releases made in the inferest of Power (CS)	Gain Or 1055 between Pong & Mandi Piain(CS)	Total releases at Pong 82 Col 20-(Col 23+Col. 24 + Col. 26) (CS)	Storage or with drawal in cusecs	Storage or	fe	Losses in Pong Reservoir in acre feet	Net Storage in Pong Reservoir in T.A.F.	Reservair Eleration (ft)	Tailrace Eleyation (ft)
17	18	19	20	2/	22	23	24	25	26	27	28	29	9	30	Promoteoper: Print (or y a print of the control of	32	3.3
7007	13140	13140	20147	A contract of the contract of	18-3 G	and the second s	9000 9000	adver, 465,4 and another control of the control of	+2500 +2500	The Control of the Co	+24055 +45973	er i managementant ig a	1491	15000	24 26 5262	1312	1097
1 Fig. 1	14854	17-500 tr. 27-2007 2004 tr. 2	22008	1915/89	gashidha	ggsstepanik -	6199	A I MARKETHAN P. P. S. AND	+2000	13809	+24 553	+	491	5000	5748	1383	1089
	15976	ri ,il dina e i zena galende	a progressiona i di professo, i minimitati	Alternative management of the second	general,	- distribution) reconstruction (management)	3 199	marining (Villeria)	+2000	and the communication of the section	6414	-	128	5000	587 1	1388	1092
	g makene in a county of	e menenga in menengan naka menengan nakan na Inggarapan nakan naka Jangarapan nakan nak			gari Agrica, Egission Stadios — PP (Page 1986/1996) — 1 k an - 1 k an - 1	and the second s	en galangan da kan ara ng galangan da kan	harr - delangdallikadeddallifer (*) d-	And the second s	er zez giane gelen aprila m. i dium. i distributant protessa este est. i i i i i Bilin di serie di ser	amadalama o cicadoler diadasa yakeegaashiisa e maanaa diadasa daa ahaa daa	is or commentational the second contraction of the second contraction	he ja kunggangan tem atawanya dag garangan	(B) (g) / of the manufacture and add (g) (g) of things (g) (g) the supposed (g)	POLIT GEORGE SINGS	dauragas , , , , , , , , , , , , , , , , , , ,	Major distribution (Annual Property of the Control
7154	5 5 0	51850	28374	gapen.	political processing and the second processi	gaspriddig Dagis Jamin 1967 - x x x x y Jackseyangerinnon	626	Company Company	12000	The state of the state of	-10903		218	francisco de malacera manuale communes, menganico aparfei S	memoran i n i recimer commo remova memoral	1381	1094
4502	18581	858 2	23134	destruction of	giventing	d/+ blattji u - j - tate yaandenbelin s	epital Ba	gg/rstreigg	+1000	22184	-15589	_	967	3500	4668	1360	1093
4500		780	382	grent line	internation on management comments	, traiged.	ggessert 18	gations/set .	+ 500	16882	-14128		849	10500	3810	1342	1091
32 7	-5-7	8870	12081	g remains	egitativ vya	Searcheck	gri wedning		+ 500	1587	-8995	-	5 58	105 00	3242	1330	1089
25.57	9 36 0	Serve Apper access of 1 to be served as a	e comes and the		mara, arian tanandar d	andress supers are	action of the second of the se	ration in summarise trains assessed	+ 500	n de la company	·+404	these	25	10500	greenhouseholy - Fully Indepthies Authorisementally	1320	1085
The state of the s	9460	a Company comment comment	tion of court of	285	190	2661	1 Indonesia	Shape.	+ 500	9618	-6103		342	10500		1322	88 01
3 4 3 5	4525	14525	18360	Space 17	gge 4db	garantege	843	ggstragg	+ 500	17017	-13731	-	851	13000	1989	1303	1001
3.460	58C)	5 80 0	9269	5612	,	5612	3657	Links	Applications	Million of the Control of the Contro	+ 2825	+	169	15000	2144	1306	1085
							The state of the s		o so de ego como d	10 mg			والمراجع والمراجع والمراجع والمراجع والمراجع والمراجع والمراجع	-	ang bakan ne talia anga at Makana anga sa panganan	and a constant of the state of	18 7 I Disputing our Live and spine and companies.
5790	12 By 22	7552	4342	Approximately a second	A contract of the contract of	and the same of th	2128	Todage 1 personal part of the	- 500	12714	-9280	-	575	15000	1554	1288	1089
	1572	5 126	2 101 6	- Committee	and the state of t	-	2014		- 500	19502	-13572	-	273	5000	1275	1277	1092
5050	5398	324 %	193/3	9 4 5 3	egopala	9453	3305	ME)	- 500	7024	# 250	+	5	5000	950	1250	1087
6790	15 398	5398	2 188	6255		62.55	5168	Annual Control of the	-500	11265	1 250	+	5	5000	9 50	1260	1088
	8 8 8	for agent sugger o specimentaria i calling			0 123	Andrews	1.746		0.582		Section 2015		and the second s	0.093	and the second second	The section of the se	the 'p roma. Agent out pages to fall game or specifications in framewood block.
	They is a firm to the control of the	(ii) 1.5 no separationary or spanishes are resolved bed	And the findings of the findin	Protocopie recognitivenes > 5 paperingue		1 decomposer 1975 - Composer-17 -	The state of the s	Andre		A STATE OF THE STA					and a superior contract of the superior of the		1
,	y you do held to be the	The state of the s	Agriculture , chara a free-1 or rejor or reserv	er 🌡 ermener i sementer iv.	Final Assert Co. Populages	in Anguari. Et age - spenjar in restja in	A comment	J	and the second s		COMP. TO COMPANY THE PROPERTY OF THE PROPERTY	- Consister					

MAF = Million Acre Feet. T.A.F. = The

		¥	and the second s	Deletin - / States - con	The state of the s	X
6ross head (ft) (of 32-co. 33	Losees in Perstock (#)	Net head (ft)	head (##)	Efficiency e'	Power in M. W Q. H. E. J. H. 800	Period
34	35	36	37	38	39	40
225	8	217	190	0.84	117	July
285	8	277	247	0'84	152	AU9
294	10	284	280	0.85	269	Sept 1-1
296	10	286	285	082	375	11.2
287 267 251	10	277 257 241	28 2 267 249	0:82 0:83 0:94	416	Nov
241	5	238	236	0.84	194 57	Dec.
234	10	224	231	0.84	159	Feb
212	10	202	213	0.8 2		Mar.
221	and the second	221	211	085		APY
100	10	189	205	0 '8 5	I 88	May
185	10	175	182	0.83	Carlotter Sections of Control of	June 1-16
173	6	167	177	0,81	83	11-20
172	10	162	164	0.81	127	21-31 M.A.F

Physical care and an annual contract.	un di eri'i b
•	A Section 1
3 5 9	VIERESTOF POWE
JES RELEA HAKRA FOR (E. CANALS	
F & S	20 6
BHAKES BHAKES SIKE CAL	2 E C
a mag	RELEASES I
DAI	4
14	15
Marie de la compressión de la	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1
Behaviors - contributions and the second physical physical designation of the second se	And the second s
ighteachth.	Approximates
	productive models et this
- September 198	Constitution desires
reportability and a second of	AND STREET, ST
i	E representation of 1999s
Application of the second of t	According to the second
gradovina-idi	Annual Company of the
- Amademic Control of the Control of	Jiv will before the
CPT-ASMASA-REGER	Specified Substitution
ar - pomiliyada	d commence and a second and a s
To provide a register with the a contract	
	C VIV
9094	-representative leader) (344)
2851	of the Addressing Total
engineerings."	Jenson × ±16.0%
5612	2575
Specification of the state of t	्र काञ्चलक्ष्युः । परमञ्जूषकालक्ष्यक्षा । मा काम्यलं रो जा । र
to the second with the second	ra ∯ e.e. iparini ameninae
	próque 40%-1 y delto
about ming the	en e
9453	erinderija in die en
6255	
V = J J	end - Security (1984)
Annual control of the	0.154
Common state of the state of th	The second secon
appearance Benefit of the Committee of t	managan (1911) ang
A. 6	

*	gi generatik (1979) 187 dan (1996) - magamang (1996) - magamang dagan generatik (1979) 187 dan (1996)	Δ	anderweige that have a property to the second members of the secon	and a second supplementary of the second	der Milderen – Abusprop Al-Mit-suf-autori erhaltsterssoria, de regen-vest d	ianteri sebagainasse takapat se millio korrene ali refigijos	Marketine See Brown (1920) 1 Account and 2 A	BHA	KRA	e ^{ng} 1 e petgene	and and the second of the sec	sengas university of the unique	g ngarian ng g i sanggamen	and Sec. 1
PERIOD	SUTLEJAT BHAKRA	SUPPLIES DIVERTED THROUGH B.S., LIMIT TO 7500 CS(COL.3 OF SHEET IOF 3)	TOTAL INFLOW AT BHAKRA	REQUIREMENT OF RAJASTHAN CANALS AT RUPAR CCS)	SUPPLIES DELIVERED. TO RAJ. CANALSAFTER APPLYING RES. FACTOR DURING DEPLETION PERIOD PROPERTION	DELHI DRINKING WATER SUPPLYING (CS)	TOTAL REQURIMENTS OF PUNJAB CANALS AT RUPAR CCS)	SUPPLIES DELIVERED TO PL CANAL AFTER A PPLYING RESFACTOR DURING DEPLETION PERIOD® 100%CCS 2	TOTAL SUPPLIES DELIVERED TO BOTH RAJASTHAN AN PUNUAB CANAISAT RUPAR(CS) (COL6+COD+COL.9)	CONTRIBUTION FROM JAMUNA	GAIN OR LOSS BETWEEN BHAKRA AND RUPER CC S)	RELEASES MADE AT BHAKRA FOR RUFAR CANALS COLID-(COLIMCOLIME)	SUPPLIES RELEASED AT BHAKRA FOR HARIKE CANALS CCSO	INTERESTOF POWER
- and-van	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	ter feller fra feller f Germanne fra feller fr		SPACITIC - (SPC NOT THE NACACIE - (SPC NOT - LAUE AND		CONTRACTOR OF THE PROPERTY OF		medjen vimet top, in province	And consequences are present to the consequence of	englasse meri internazionale in in in in proposition della laggia engla in accessivatione della compania della	reference in the control of the cont	Services of the company of management problems of the company of t	THE PROPERTY OF THE PROPERTY O	Service Control of Con	in the restriction will be
JULY	49981	7500	57431	420	420	325	22493	22493	23238	2201	+1500	19537	eminents	Seminarian
AUGUST	53263	7500	60763	420	420	325	22493	22493	23238	3595	+1500	18143	Secretary A 1 - decay selection () the mystellal space year participates remarks in many of the secretary of the secret	Separation of the separate sep
SEP. 1-10	33944	7500	41444	540	540	325	263 5 5	26355	27220	4045	+ 500	22675	dere destret ter	TORPILA HONG
1120	24909	7500	32409	540	540	3 2 5	26355	26355	27220	1615	+ 500	25105	New York And Annual Control of the C	salani sertanikin
	n Milliande (d. in. Amir e Abell Inng - E) - Milliande property of 10, 10, 20, 20, 20, 20	and reference and particular and use of management regularization of the second	Anthonorum on the species a material contribution on the			The state of the s	the other way are a little of the said give a give a given and	eggerengen (textus is seglentered textus special and an experience of the second	The state of the s	distributed in the second of t	A Section of the sect	The second of th	The state of the s	March of America (1995) Washington (1995) Washin
SEP. 21-30	alemmer our Toulithin community of the first of the community of the commu	7500	26746	540	540	325	26355	26355	27220	1517	< 50 °C	25203	general property and the second	Manufacture and the control of the c
OCT.	10878	6454	17332	480	480	325	26624	26624	27429		Section of the sectio	27429	enderstander (n. 1921). De service (n. 1921)	√dwrite (in-principle
MOV.	6208	3077	9225	480	480	325	24043	24043	24848	- Martinespenger	ubstranting.	24848	t mate librarancespings	Barrer (All State of the Control of
DEC	4738	2259	6997	336	336	325	16420	16420	17081	OF SPROSECULAR	+ 100	16981	Book responde	Schoolswal.
America de Consultativo de America de Consultativo de la Consultativo de Consu	t deglassing (3) - potencial deglassing deglassing committee (1874) - 1874) - 1	g 5 The series of the form of the series of the	i de la compania del compania de la compania del compania de la compania del compa	,	S appropried of the St.	TE TE TE TE TE TE TE TE TE TE TE TE TE T	A CONTRACTOR OF THE CONTRACTOR	1	and a second control of the	· · · · · · · · · · · · · · · · · · ·	The state of the s			
JAN.	4328	2039	6367	370	270	325	13261	13261	13856	additions with	+ 500	13556	9094	wattekhlarvente.
FEB.	4400	2259	46659	366	366	325	17708	7708	18399	t ju malayas .	+ 400	17909	2851	Physiological gray
MAR.	4786	3402	8188	420	420	325	20056	20056	20801	springsbastilaris.	+ 200	20601	Company of the Control of the Contro	الله ميهود باله ميهود معهم مهمور بادر
APR.	5923	5671	12594	300	300	325	13088	13088	13713	esphisasies	- 300	14013	5612	2575
50 TS 7650, De s'elle type transport management and config	and the state of t	of hanney blanks and the later of the 1974 of			1	7 7 to	24049			2 1 kg mpts 4	The street of th	Commence of the state of the st	the state of the s	en en en ar
MAY	15472	7500	22972	480	480	325	26068	260 68	26873	Sometiments	- 600	27473	planteningerens	programme, grippine i syndigene official in the character way industrial grip
JUNEI-10		7500	31410	480	480	325	26499	26499	27304	granderstanderstanderstanderstanderstanderstanderstanderstanderstanderstanderstanderstanderstanderstanderstand	600	27904	All control of the co	Historianisti Pilanis (n. 1874)
11-20	30007	7500	37507	480	480	325	26499	26499	27304	Contradopage	-600	27904	9453	erende e usas
-	38045	7500	45545	480	480	325	26499	26499	27304	dissenseshings	-600	27904	6255	Arpha phaga
M.A.F.	13.329	and the same of th	*	0.304			15.533	on the state of th	and the same of th	0.503	and the country of th	The same of the sa		0 · 15
Statement de description de la constitución de la c	and the second s						TO THE STATE OF TH	ment mage, or an out-plantagement - 1 is a rate. I represent mage and the contract of the cont		<u> </u>			in the state of the second specific country is specified to second in the second specified country in the second s	were the second of the second
				*				*	CS = CU	SECS			М	AF ==

A AT BHAKRA	STORA OF	STORAGE OR WITHORAWAL	SSES IN RULERVOIR ACEL TO	NET ST SA TAN	RESURVOIR		GROSS HEAD (FT)	NET HEAD (FT.) (CC(23-4)	MEAN HEAD(FT)	EFFICIENCY (E)	WER IN BHAK	POWER AT DEHAR POWER PLANT (M.W.)	POWER AT PONG	OLIZ OF SHEET 1 PT	CANAL OWER HOUSE	TOTAL	PERIOD
	The second transfer and a final	man garan da	19	20 	2 !	22	23	24	25	25	27	28	29 29	~ L			The state of the s
19537	379.4	+2352		THE THE STREET	-	***			A COMMAND SERVE	1	: : . }		TO Section 2015	T. I. and I was consider review to the control of the control	30	31	32
18143	42620	+2642	desires assumed on the title and it are absent		1590		423	416	357	0.83	400	The same of the sa	The state of the same analysis supplied to		The state opposition for the special section () the state opposition (
22675	, 18769	4 375	2.1 9.40	*	1570	*	500	498	456	0.84	590	5 3 G 5 2 3	127	the terror and the same of the same	1	1291	JULY
25105	7304	- 146			1579		508	504	500	- 4	797	5 5	260	. At the said	S J	1419	AUGU
The second second second second		The state of the s		7686	1692	1172	510	506	505	0.83	89!	512	4	· · · First stransportan	-	1735	SEP I
25203	543	+ 30	3000	7714	1683	1175		Temperand of a market and a market	- displacement of the control of the control]	the second secon	And the second	375	The second second	-	1932	-
1	- 6007	- 626	8000				511	507	507	0.83	900	- 1 d	505	en bestern vista ventas v	-	10 mg	The article of the second of the second of
÷	-1556	- 734	(000	6145	1668	1173	495	491	499	○.83	963	447	4.6			*	SEP 21
16981	- 7054	- 6 9	5000	5915	1642	1172	470	466	478	೧⋅83	837	225	300	**	3	1982	المنافقين المستحدين المنافقينين. والمنافقين المستحدين المنافقينين
1			i_	TOTAL IN B I GAR	1000	- 107	The same of the sa	-150	458	0.84	553	167	19-	rate or according	Ž		NOV
227		1016	6000	4493	1538	the same of the sa	man at the contract of the con	-		-		provide spice and has report to the spice of	M4		7		DEC.
2095		- 795	6000	3693	1555	1171		413	431	0.85	70é	51	The same of the sa	- Arts y sang		1068	
20601	-1243	- 770	8000	2914		1171	384	380	3 96	0 84	588	167	55	and the second s	-	1068	7711 01 0000000000000000000000000000000
	- S	576	10000	2:28	1485	1.7	347	343	36:	∩ 83	523	250	24)	A grown case (see) as		was or many a great way or	
				Militaria Josephinia	a man come.	resident de la companya de la compan	314	310	3265	0.82	501	410	and seeper Lings.	4	-	1068	MAR.
27.173	4 77	. 5)	10000	2039	112			to protessing the second of th			•	Market and the second of the s		e e dinasta e e A		The second of the second	APR.
	35.6	76.	Std. In or a semination of the semination of	PER IT AND THE	1466	B. at arms and	293	289	299	0.80	557	530	188		Committee of the Commit		maker and a manager and a special section of the se
	+ 150	+ 3	3 30 0 .	1972	1470	,	297	293	291	0.80	550	530	250	-5-		429	MAY
34159	1,355	+227	3000	2195	1462	3.5	287	Commission of the American Property of the Confession of the American Property of the American Property of the Confession of the Confessio	288	0.80	729	530	83	The state of the s		495	JUNE -
Company of the Compan	and the second of the second o	A STATE AND STAT	A Commence of the second of th		770	Tandy	302	298	29:	0.80	673	530	127	1	province was "Force	484	11-2
The second secon	and the party of the state of t		TO TOPPE I COMMERCIAL ASSESSMENT COMPRESSMENT COMPRESSMENT COMPRESSMENT COMPRESSMENT COMPRESSMENT COMPRESSMENT	All height with despendent markets of the designation of seconds beginning to the second of the seco	No. 40) page agreement or - all related by Spirites agreement became		mante promining and in more considerable	-	t y g g Market channelers - excess see us us confirs t	The second secon	The second of th		that is now in a financial large with	and company of the company of	The state of the s	e c rendran i roek men i just i roek ji	21-3 M A E
ION ACI	RE FEET		was a ser to be one commence and	D. C. and Agent and constituting Agents in Assets, and applications		The second section of the second section of the second section			Pro-residence - elected residence - confirmation of the confirmati	The the state with the second graph	the last of the special part of the special page.	American control of the control of t	· Jih rings y adapter Manghanan hang dia badilangkat, Ay ya			and the second s	M.A.F

coefficient of 0.7 for Bhakra reservoir. Using meteorological data and normal meterological condition, the average monthly evaporation rates have been calculated. The average annual evaporation is around 5 ft. (4.80 ft) and the monthly values from June to May are 0.73, 0.43, 0.32, 0.39, 0.34, 0.25, 0.17 0.16, 0.21, 0.37, 0.63, 0.84 ft respectively. These evaporation rates were used for Pong reservoir also.

4.3.5 Elevation area capacity curves

Elevation area capacity relationships for Bhakra and Pong reservoirs were obtained in tabular and graphical form from B.D.O. and B.B.M.B. These were defined by sixteen matched points per reservoir and are shown in Table 4.4. For intermediate values linear interpolation was adopted. These data were used to define minimum storage, the maximum capacity of the reservoir and also the rule curve.

4.3.6 Data for energy generation

Power is generated in the system at Bhakra, Pong, Dehar and Nangal including Ganguwal and Kotla power houses. Rajendra Nagar and other small systems in tributtines by are ignored in the study.

The energy generated at Nangal is assumed to be constant (154 MW) as in the B.D.O. studies. Dehar is a constant head power plant and hence the head and efficiency at Dehar are assumed as constant and energy generation are directly

TABLE 4.4 <u>ELEVATION-AREA-CAPACITY OF BHAKRA AND PONG</u>
PESERVOIRS

Point	Bha	akra Res	ervoir	Pon	g Reser	voir
<u> </u>	Elevation in Ft.	Area in Acres	Capacity in Acre Ft.	Elevation in Ft.	Area in Acres	Capacity in Acre Ft.
1	1400	9550	1037156	12 <u>6</u> 0	19182	1044000
2	1420	9830	1232568	1270	22041	1250000
3	1440	11620	1448854	1280	25089	1 <u>4</u> 84000
4	1460	11880	1685808	1290	28784	1754000
5	1480	148 <u>9</u> 0	1955734	1300	32337	2060000
<u>6</u>	1500	15970	2266902	1310	35686	2 <u>40</u> 2000
7	1520	18820	2617696	1320	38960	2776000
8	1540	20870	3017898	1330	42251	3180000
9	1560	23130	3461558	1340	45821	3620000
10	1580	25370	3950592	1350	49336	4096000 .
11	1600	28050	4489236	1360	52792	4606000
12	1620	30830	5082934	1370	55744	5 <u>1</u> 50000
13	1640	34000	57 3 6628	1380	58629	5722000
14	1660	37050	6453038	1390	61612	6324000
15	1680	40150	72 <u>3</u> 1460	1400	64.404	<u>6</u> 952000
16	1700	43400	8074112	1410	67048	7610000

related to their discharge in Beas-Sutlej link.

For Bhakra and Pong reservoir, the head on the turbine depends upon the reservoir storage and downstream releases and the efficiency of the system depends upon the net heads and these vary from month to month. B.D.O. has considered the details of planned storage and releases for estimating the net head and efficiencies for dry, dependable and average years (Tables 4.1 to 4.3).

From a comparison of the heads, losses and efficiencies in dry, dependable and average years in the B.D.O. studies, it is concluded that, for the purpose of the study, head loss may be considered as constant equal to 4 ft and 8 ft for Bhakra and Pong power plants. Efficiencies may be considered to vary piecewise linearly as the function of the net head. The efficiency (?) net head(H) relationship adopted in this study are indicated in Table 4.5. It is possible to use a better procedure for estimating the energy generated more accurately.

4.3.7. Link capacities

The capacity of Beas Sutlej link is assumed to be 7500 cusecs in BBMB studies. The capacity of the river Sutlej and Beas are considered to 50,000 cusecs each. The lower limit for link flows is assumed to be zero.

TABLE 4.5 HEAD-EFFICIENCY RELATIONSHIPS

Bhaki	ra Power Plant	Pong P	ower Plant
Head Ft.	Efficiency	Head Ft.	Efficiency
		Digwyddiolaeg y dalan ym cheff y rhynnog y y yr ei far y digwydd y flannif y rhynnif y rhynnif y rhynnif y rhynn y dy y flyn y dy y	
Below 300	0.80	Below 17 0	0.81
300	0.80	170	0.81
325	0.81	180	0.83
350	0.82	190	0.84
375	0.83	200	0.85
400	0.84	215	0.85
425	0.85	241	0.838
450	0.84	267	0.826
475	0.83	280	0.82
abo v e 475	0.83	above 280	0.82

- 4.4 Study of Planned Operation
- 4.4.1 Planned operation

The planned operation for dry, dependable and average years are given in Tables 4.1 to 4.3. It is proposed to study the planned operation of the system in order that the characteristic of the system can be understood and improvement can be made in the operation of the system. The following additional assumptions were made for studying the planned operation.

- i) Only Bhakra is considered as spill reservoir, and
- ii) The irrigation demands were initially taken as average year demands. However because the inflow in large number of years were much less than the average demand. it was decided to modify the demand in the 5th year as a dry year demand.
- B.D.O. has suggested rule curves for dry, dependable and average years while the study required rule curves for dry, average and wet states. The rule curve for average and dry states were adopted from B.D.O. studies and rule curve for wet states was estimated from these two and used in the study. These are indicated in Table 4.6.

4.4.2. Value judgements

It is necessary to define the relative priorities between and among storages and demands. From a consideration of the characteristics of the system, the following general conclusions were derived:

- i) Storage in Bhakra reservoir is much more valuable than in Pong reservoir because of its high head and its ability to supply irrigation water to all demand nodes;
- ii) Demand at Nangal is more valuable than that of Rupar and Harike because of power generation benefits;
- iii) Releases in the interest of power from Bhakra have a lower priority;
- iv) Storage is more valuable in a dry year than in wet or average years; and
- v) Diversion through Dehar should have greater priority than diversion through Pong.

Using some priority ranks for average, dry and wet years and keeping in mind the above priorities several sets of ranks for meeting the irrigation demands were used and tested. From the results, the values shown in Table 4.7 were adopted for subsequent studies.

In order to consider the effect of relative priorities between the storages and for different hydrologic states, sixteen sets of priority ranks (Table 4.8) were used along with the planned operation and these constitute the simulation study of the planned operation of the system. The value of X_1 and X_2 which define the hydrologic state of the system were varied between 0.7 and 1.0 for X_1 and 1.0 to 1.2 for X_2 respectively. The results of simulation include the details of monthly, annual and total period summaries of the process.

TABLE 4.6 RULE CURVES+

1. Bhak	1. Bhakra Reservoir	ir						Max	kimum. C	apaci ty	Maximum Capacity=7.644 m.a.	m·a.
Hydrologic State	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
Average	0.2873	0.5937	0.9387.	1.0000	0.9260	0.8032	0.8032 0.7213 0.5877 0.4829	0.5877	0.4829	0.3812	2 0.3045 0.2	0.2
Dry	0.2224	0.4213	0.6267	0.6720	0.6478		0.6091 0.5477 0.4626 0.3768 0.3003	0.4626	0.3768	0.3003	3 0.2415 0.2	0.2
Wet	0.2873	0.6297	0.9750	0.9750 1.0000	0.9327	0.8166	0.9327 0.8166 0.7414 0.6145 0.5164 0.4214 0.3514	0.6145	0.5164	0.421	1 0.3514	0.3
2. Pong	2. Pong Reservoir	C ₁						Max	. Capac:	ity = 6	Max. Capacity = 6.952 m.a.f.	a.f.
Hydrologic State	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Ma
Average	0.1367	0.3491	0.7568	0.7568 0.8125	0,6714	0.5480	0,6714 0.5480 0.4662 0.4611 0.4105 0.2862 0.3083	0.4611	0.4105	0.2862	0.3083	0.2
$Dr_{\mathcal{S}}$	0.1504	0.2475	0.2887	0.2645	0.27.69	0.1722	0.1722 0.1682 0.1608 0.1588 0.1516 0.1552	0.1608	0.1588	0.1516	0.1552	0.1
Wet	0.1367	0.3769	0.7600	0.7600 0.8125	0.6781	0.5614	0.5614 0.4863 0.4879 0.4440 0.3264 0.3477	0.4879	0.4440	0.3264	0.3477	0.2
												-

⁺ Desired end of month storage level as a ratio of full capacity.

TABLE 4.7 PRIORITY RANKS FOR IRRIGATION AND POWER DEMANDS

Hydrolo- gic State		2	Name	of No	de	·		
	Bhakra	Pong	Pandoh	Dehar	Nangal	Rupar	Harike	Muke- rian
Average	14	20	20	8	JÙ	12	16	20
Dry	14	20	20	8	10	12	16 .	20
Wet	14	20	20	8	10	12	16	20

TABLE 4.8 PRIORITY RANKS FOR RULE CURVES

Beservoir	Hvdrologic							Simu	Simulation Runs	n Rui	າຮ					
	State	1	2	27	4	N	9	· _	ω	6	10	11	12	13 14	. 15	16
Bhakra	Average Dry Net Average Dry	10 8 12 14 12 16	6 4 6 7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	20 18 22 22 18 18	14 12 16 12 12	20 15 20 50 50	25 25 60 60 60	30 30 50 50 50	20 18 22 25 25 25	6 4 1 1 2 1 2 1 1 6 1 6 1 6 1 6 1 6 1 6 1 6	15 10 15 15	10 8 8 12 25 25 25	14 12 16 25 25 25	8 16 6 12 8 16 120 35 120 35	12 88 12 13 110 110 110 110 110 110 110 110 110	20 20 20 20 20 20

- 4.4.3 Results and conclusions
- i) Various values of X_1 and X_2 to define the hydrologic states of the system were tried and finally it was concluded that values of $X_1 = 0.90$ and $X_2 = 1.10$ was seen reasonable for the Beas-Sutlej system;
- ii) Initially Bhakra reservoir alone was taken as spill reservoir. For some of the cases considered, Pong reservoir became full after about sixth year and because of the limit of the capacity of Beas-Sutlej link and no spill permitted at Pong there is no feasible solution and this indicated that Pong should also be considered as a spill reservoir;
- than the inflows and in large number of years, there is scarcity particularly from March to June and these occured at Rupar and Hariko which had the lowest priority. This indicated that in order to keep to deficit within limits, it is necessary to reduce the demands in some of the years. The inflows in 8th, loth and 12th years are less by around five million acre ft each than the average year demands, and so the demand in these years are to be reduced to atleast dependable year demands;
- iv) Variation of the priority ranking between storages for different hydrologic states indicated that:
- a) Priority of storage at Pong should be less than that of Bhakra;

- b) Priority for storage at Bhakra should be lower than that for demands and can at best be equal to that for the lowest priority demand;
- Priority for storage in average and wet years should be the same. The priority for storages in a dry year may be slightly higher in order to avoid the large deficit at the end of water year or in the beginning of next water year; and v)

 It is necessary to modify the rule curves for a better operation.

4.5 Improvements in Reservoir Operation

The simulation study of planned operation of Beas - Sutlej system indicate that the operation of the system can be improved significantly by modifying the rule curves and improving the value judgement for demands and storage under improved operating rule curve.

4.5.1 Modification of the rule curve

The planned operation of B.D.O. adopted in the study is indicated in Table 4.6. It shows that planned storage at the end of May and June as well as other months are different for the three states. The storage at the end of May is influenced by the inflows in the previous year and it should reflect the desirability of carryover in wet years and deplotion in dry years, but in June, the state depends very much on the carry-over of the previous year and the inflow and

demand in a year may differ very much from the end of the year storage. It is hence not possible to adopt different initially desirable storages at the end of June.

Using the general criteria that planned end of June storage should be the same in each reservoir for all states; the end of the year storage should reflect the possibilities of carry over and depletion; the reservoir fills up rapidly in the months of June to September and depletes from October to May or June, several modifications for the desired monthly storage levels for the different states in the two reservoirs were tried and the following rule curves are considered to be an improvement over the planned operation of B.D.O. (Table 4.9). It may be seen that the reservoir fills up quicker in an average year than in dry year and in turn it fills up quicker in a wet year than in an average year. The end of year storage in a dry year is less than that in an average year which in turn is less than that in a wet year. The general trend of the rule curve is similar to that of the planned operation except for some further modification in the end of month storages for August and April.

4.5.2 Ranking of priorities

Simulation of the planned studies as well as the improved operation indicate diversion through Pong from Harike while storage and capacity were available through Dehar and Bhakra. In order to eliminate this problem, the priority for

TABLE 4.9 MODIFIED RULE CURVEST

Max.Capacity = 7.644 m.a.f.

1. Bhakra Reservoir

Hydrologic State	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March		April	May
Average	.3438	. 5642	9806.	.9795	.8965	.7737		.6918 .5582	.4534	.3517	7 .2950		.2578
Dry	.3438	.4567	.6621	.7074	.6832	.6445	. 5831	1 .4980	.4122	.3357	7 .2769		.2578
Wet	.3438	. 5997	.9750	0066	.9032	.7871	7119	9 .5850	.4869	.3919	.3419		. 2908
2. Pong Reservoir	leservoi	r							Max.	Max. Capacity	ty = 6.9	= 6.952 m.a.f.	2.f.
Hydrologic State	June	July	Aug.	Sept.	. Oct.		Nov. De	Dec. J	Jan• I	Feb.	Mar.	April	May
Average	.1367	.3491	.7568	.8125	5 .6714		5480 .4	. 4662	4611	.4105	.2862	.2483	.223
Dry	.1367	-2338	.2750	.2508	3 .2032	. •	1585	.1545	·	.1451	.1379	.1370	.136
Wet	.1367	.3769	.7600	.8125	5 .6781	•	2614 .	.4863	. 4879	.4440	.3264	.2877	.277
													One of the last
deficiently tendent and control position above tendent and improgramme provides the	Section of the sectio	A CONTRACTOR OF THE PARTY OF TH	The state of the s										

⁺ Desired end of month storage level as a ratio of full capacity.

demand at Harike was reduced by changing the rank from 16 to 25.

In order to study the priority in meeting the demand at Bhakra exclusively with the interest of power, four simulation runs were done with changing demands as indicated in Table 4.10 and with priorities as indicated in Table 4.11.

4.5.3 Evaluation of system performance

The planned operation as per B.D.O. meets the specified irrigation and power demands. The planned energy generation in the components as well as the total system are taken from Tables 4.1 to 4.3 and are shown in Table 4.12.

Energy generated as well as the irrigation deficits vary over the months and over the years. For the purpose of the study the following details of the performance of the system are considered important (Tables 4.13 to 4.16).

- i) Total annual and monthly irrigation deficits;
- ii) Power generation at (Bhakra and Dehar), Pong, and the total power generation of the system in Kharif season and non-kharif season and water year respectively;
- iii) The surplus or deficit of power in each of the subsystems in Kharif season, non-kharif season and water year respectively, in comparison to planned values;
- iv) An earlier study (Rao, 1976) of the system indicated that:

TABLE 4.10 POWER DEMAND AT BHAKRA

Years	62	Simulation Runs		
		II	III	ΙΛ
RECORD AND AND AND THE COMMENT AND				
1,2,3,4,6,7,9,11,13	Average	Average	Nil	Nil
5	Dry	Dry	LiN	Dry
8, 10, 12	Dependable	Dependable	Nil	Nil
THE BUTTER	В. П. ()			

(Values as specified by B.D.O.)

TABLE 4.11 MODIFIED PRIORITY RANKS

φ φ	- <u>-</u>	Hydrologic		Simulation Run		
Average 35 26 35 Dry 35 26 35 Wet 35 26 35 Average 30 30 30 Dry 30 25 30 Average 50 50 50 Dry 50 50 50 Wet 50 50 50 Wet 50 50 50 Wet 50 50 50	T tem	State	Ι	II	III	IV
Dry 35 26 35 Wet 35 26 35 Average 30 30 30 Dry 30 25 30 Wet 30 30 30 Average 50 50 50 Dry 50 50 50 Wet 50 50 50 Wet 50 50 50	Demand	Average	35	56	35	09
Wet 35 26 35 Average 30 30 30 Dry 30 25 30 Wet 30 30 30 Average 50 50 50 Dry 50 25 50 Wet 50 50 50	1 1	Dry	35	56	. 35	09
Average 50 50 30 Dry 30 25 30 Wet 30 30 30 Average 50 50 50 Dry 50 25 50 Wet 50 50 50 Wet 50 50 50	Bhakra	Wet	35	56	35	09
Average 30 30 30 Dry 30 25 30 Wet 30 30 30 Average 50 50 50 Dry 50 25 50 Wet 50 50 50						
Dry 30 25 30 Wet 30 30 30 Average 50 50 50 Dry 50 25 50 Wet 50 50 50	Bhakra	Average	30	30	30	30
Wet 30 30 30 Average 50 50 50 Dry 50 25 50 Wet 50 50 50	3 4 5) VY(I	30	rs Ca	30	30
Average 50 50 50 50 ge Dry 50 50 50 50 80 50	थ अ उ	Wet	30	30	30	30
Average 50 50 50 ge Dry 50 25 50 Wet 50 50 50	ALTHOUGH STATE OF STA					
ge Dry 50 25 50 50 Wet 50 50	Ропо	Average	50	50	50	50
Wet 50 50	1 Car 6	A.L.(50	25	50	90
	2 2 2 2	Wet	50	50	50	50

- 1) Conjunctive use of surface and ground water resources is necessary;
- Since excess energy is available in Kharif season, this may be used for pumping ground water to meet part of the irrigation demand and to this extent, the surface water releases may be reduced. The earlier study indicated that in Bhakra reservoir in Kharif season about 1500 acre ft. per month of water is required to generate 1 MW of power and this will pump 6000 acre ft. of ground water. Hence 1 MW of excess energy indicates a potential for saving 4500 acre ft of water from Bhakra releases and thus augmenting storage;
- Tables 4.13 to 4.16 increases the head and energy generated in the subsequent period and this is not taken into account in this study.

Yet this amount of water is available for irrigation and this may meet partly or completely the irrigation deficits in the water year. Net water deficit, if any, in the water year is indicated in column 26 of Tables 4.13 to 4.16.

This deficit may be met by diverting energy from outside the system and the amount of energy in MW months required for meeting these deficits are indicated in column 27 of Tables 4.13 to 4.16.

TABLE 4.12 PLANNED ENERGY + GENERATION

							1	1 3 4 4	Tr the Water Year	ear
		T . 17h	rif Se	ason	In Non Kharif Season	Kharif	Season	TT1 0110	Dong	Total +
Hydrologic State	Total inflow In Andrea Pong Tota-	Bhakra Pong Total	Pong	Total [†]	Bhakra +	Pong	Pong Total	bhakra + Dehar	9 TO T	
		Dehar			Denar					
									0380	16498
	1	COF	רפפר	8093	6168	1159	8405	12210	2071	i I
Average	28288/60	2010	-i -j -i			f :		0303	751	11992
ı		0707	573	6315	4421	178	26.77	777		
	17844884	7-7-1	`			(1000	1.535	14051
Defendable	22971018	5513	877	7160	5155	0 20	1600)) ;		
	•									
								The state of the s		

+ Includes energy generated at Nangal ++ Energy is in M.W.months

4.5.4 Discussion of results

A comparison of the generated energy in simulation runs with planned demand indicates that surplus energy is generated even in a dry year during the Kharif period and there is a deficit of energy during rabi season in average and dry years. Rao (1976) has suggested the use of surplus energy in Kharif to pump ground water by tube wells and hence reduce the surface water releases in Kharif for meeting irrigation demands. This will result in a higher storage during and at the end of filling period. It will also lead the availability of larger amount of water and energy in the depletion period.

Results of simulation run I indicate that irrigation and energy deficits are eliminated in a number of years and are otherwise reduced in other years. For example the irrigation deficits in years 2nd, 6th, 11th and 13th are eliminated and the irrigation deficits in years 3, 7, 9 and 10 are reduced. It is also seen that 20 to 24 MW months of energy will be required to eliminate the deficits in years 7 and 10 respectively. The energy requirements in years 3rd and 9th are of a much higher order, viz, 136 and 483 MW months. If energy of these magnitudes is available from outside the system, it is possible to eliminate irrigation deficits even in these years provided that adequate tube wells are also available.

Simulation Run II assumes a higher priority for maintaining storage in dry years in comparision to wet years. The results indicate that the operation is similar upto 6th year and then differs from 7th year onwards, while the variations are erratic from 8th to 11th year. The energy deficit is much larger in the 12th year in Kharif period and the energy surplus is smaller in the 13th year in simulation Run II in comparison to simulation Run I. Furthermore the amount of energy to be imported from outside for meeting the irrigation deficits is also larger in 7th, 9th, 10th and 12th years in simulation Run II. It is also seen that surpluses and deficits of energy are generally smaller in simulation Run II than those in simulation Run I.

Simulation Run III eliminates release from Bhakra on consideration of power. Simulation Run IV considers power demand at Bhakra only for the dry year 5th with the lowest priority. The results indicate that -

- i) The fluctuation in energy is larger for Run III than Run IV:
- ii) There is energy deficit in the 5th year in rabi season in Run III even though there is a surplus in an entire year:
- iii) The energy generation in Run III is smaller than that of Run IV by 126 MW months;
- iv) There is a large system loss in month 3rd of 6th year for Run III which is absent than Run IV; and

v) The irrigation deficit for 6th year is smaller for Run III than for Run IV and comparable in other years.

From the above results it is generally seen that energy releases from Bhakra need not be specified. Depending upon the relative value of irrigation deficit versus energy, at best those may be specified for dry years. In the absence of such value systems, it is inferred that Simulation Run IV is preferable.

4.6 Conclusions

The study indicates the following:

- i) Rule curves and priorities as given in Tables 4.9 and 4.11;
- ii) Irrigation demands and priorities are indicated in Tables 4.1 to 4.3 and 4.7; and
- iii) Power demands and priorities as indicated for Simulation Run IV in Tables 4.10 and 4.11 lead to an improved operation of the system.

Further improvement of the system performance is possible by modification of the simulation programme in the following respects:

- i) Incorporation of better algorithm for estimating the energy generation in the system;
- ii) In some time periods diversion through Pong are indicated while capacity through Dehar and at Bhakra are available.

In these cases it is necessary to divert flow through Dehar even though the out of Kilter algerithm indicates diversion through Pong;

- iii) Incorporation of subroutine to determine energy surpluses if any during kharif period, utilization of available tube wells for pumping ground water during this period to the extent necessary in conjunction with surface water releases, and modifications in SIMYLD II programme for correcting, releases and storages appropriately; and
- iv) Incorporation of flow and demand forecasting as well as suitable flexible control rules for the rule curves.

-	Managada da da sa	<u>u</u>	Markad tradeministration in the latest accordance to the second second second second second second second second		ILTS FOR	S. Marian Ballerine		- POWI	N NO	NERA	TED -		Marie Constitution of the		*	SI	JRPLU	s (+) 0	R DE	FICIT	(-)					· y ij
f	NFLOW	9.4	IRRIGATION DEMAND	IRRIGATION	•		ER II		POW	ER I	N	7	OTAL POWER		-1	no and the water may be an in the state of	DEFICI	SURPL	and the second s	EFICIT	SURPL	I amount the areas		ACRE FT WATER THAT CAN BE	IRRIGATION DEFICIT	
	ACRE FT.	HYDR	ACRE FT.	AMOUNT IN	PETAILS	BHAKRA DÉHAR	PONG	TOTAL	-	F***********	*	-	A PONG		-	PONG		BHAK RA	7	7	-	PONG	7	STORED BY SURPLUS ENERGY IN KHARIF	AFTER USING SURPLUS ENERGY (ACRE)	POWER REQUIRE
	river for the adjustment of the last th	3	4	5	8	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	FT. /	
3	077823	WET	1786945Z	NIL	NIL	6566	1202	8538	6206	1493	8777	12772	2699	17315		-		+38		<u> </u>					NIL	NIL
2	25108845	AVRG.	21869452	922286	MAY	6536	1296	8602	6016	831	7925	1255;	2 2127	16527	+434	+ 75	+509	-152	-328	-480	+282	-253	+29	2290500	NIL	NIL
7	26838606	AVRG	27869452	1615422	49629 (MAR) 177398 (APR) 1039675 (MAY) 348720 (JUNE)	6263	1238	8271	6148	768	1994	1241	7200	16269	+ 161	+17	+178	- 20	- 391	-411	+ 141	-374	-233	801000	8/4422	/36
	2949/54	VET	27869452	NIL	NIL	6377	1127	8274	6424	1312	8814	1280	1 2439	17088	+275	-94	4181	+256	+153	+409	+531	±59	+540	814500	NIL	NIL,
	7497518	DRY.	16757756	NIL	N ''	5350	767	6867	4534	307	5919	9864	1074	12786	+358	+194	+552	+113	+179	+242	+471	+323	+794	2484000	N/L	NIĻ
	24735881	WET	27869452	2314295	448401(APR) 1624150 (MRY) 241744 (JUNE	7/24	1025	89/9	5274	844	7/46	12348	1869	16065	+1022	-196	+826	-944	- 315	-1259	+78	-511	-A33	3717000	NIL	NIL
	2735959	VET	27869452	511751	5)1751 (MAY)	6179	1234	8183	6464	867	8409	12643	2101	16592	ナフフ	+13	+90	+296	-292	+4	+373	+279	+94	405000	106751	18
A	R185809#	DEP.	21550876	NIL.	N/L	5823	879	7472	5784	221	7083	1)607	1100	14655	+310	+2	+312	+629	437	+192	+939.	-435	+504	1404000	NIL	NIL
17	4 800488	WET.	27869492	3709257	1421913(MAR) 464307(APR) 1316451 (MAY) 506586 (JUNE	6349	1155	8274	5518	423	7019	11867	1578	/5293	+247	-66	+181	-650	-736	-1386	403	802	-1205	814500	2894757	483
1	1/6/026	DEP.	21550876	567754	MAY	5532	96)	7262	\$2945	795	6.638	/250 ₁		141.					***		81	H131	+50	463500	104254	17
27	7003028	WET	27869452	1217976	4504 (APR) 1160179 (MAY) 113293 (JUNE)	60 8 0		ne entertalene de Paul Herbergi i Amerikanski beforder		+				-						or see		Marine - Special Services		796500	421476	70
2 3	3406570	DEP.	21550876	NIL	NIL	5520	830	7120	5842	333	7253	11362	1163	14373	+7	-47	-40	+687	325	362	694	372	+322	NIL	NIL	NIL
c in	755685	WET	Z7869452	1504738	MAY	6771	1025	8566	5522	909	7509	12293	1934	16075	+669	196	+4.23	46	250	896 4	23 +	446	-423	2128500	NIL	NIL

;	OTAL OFLOW	1	IRRIGATION DEMAND	IRRIGATION JULY TO:		POWI KHAI	ER IN		POWE	R IN KHAI	RIF	TOT PO	VER		f	US OR D KHARIF		3 8	USORD N KHARI		I	JSORDI DLE YE		ACRE FT WATER THAT CAN BE	PRRESATION DEFEIT	ADESTIONAL X POWER REQUIRE
1	: 1.	HYDR	ACRE FT	AMOUNT IN	DETAILS	BHAKRA	P^NG		BHAKRA F	PONG	TOTAL	BHAKRA + DEHAR	PONG	TOTAL	BHAKRA T- DEHAR		TOTAL	BHAKRA + DEHAR	PON6	TOTAL	BHAKRA T DEHAR	PONG	1 !	STORED BY SURPLUS	SURPLUS ENERGY	TO MEET DEFICE
Anna Service	2. Commence of the second	3	4	S	Control of the second sec	7	8	9	10		12	13	14	18	16	17	18	19	2	21	22	23	24	g malari , militari propagasa kanada kan Malari kanada	in the state of th	e and the extension of the extension of the second of the
30	778231	WET.	27869452	NIL	NIL	6566	1202	8538	6206	1493	8777	12772	2695	17315	+ 464	- 19	+445	+ 38	+334	+ 372	+502	+ 315	+817	2002500	NIL	NIL
24	; 10 0 895	ĄVRG	27869452	1031438	PIAY	6536	1296	8602	6006	031	7915	12542	2127	16517	+434	+75	+504	-/62	-328	- 490	+ 272	- 253	+ 19	2290500	NIL	NIL
id.	6838606	AVRG	. 2786945Z	16154~2	49679 (MAR 177398 LAPR 1039675 (MN) 348720(JUN)	6263	1238	827/	6148	768	7994	12411	2006	16265	+161	+17	+178	-20	-391	-411	+141	-374	-233	80)000	814422	136
	449154 <i>1</i>	WET	21869452	NIL	MIL	6377	1127	8274	64.44	1512	5814	12801	Z4 59	17888	+275	-94	+ 181	+256	+153°	+404	+531	159	+590	814500	NIL	NIL
1	7847518	DRY	1675-1756	NIL	NIL	5330	767	6867	4534	307	5919	9864	1074	12706	+ 3 \$8	+194	+55-2	+113	+ 129	+742	+471	+323	+\79 <i>4</i>	2484000	NIL	NIL
-	(473S 38	31 WE	T 2786945	2 2314245	44-8401 (APR 1644150 (MAY 241744 (JUN)	77124	1025	8419	5224	844	7146	12348	1864	16065	1-1022	- 196	1826	- 944	- 315	-1259	+ 78	-511	-433	37/7000	NIL	NIL
+	2755959	, WE	7 27864452	665324	MAY	6119	1234	8183	6452	861	8397	12631	२१०।	16580	+77	1 13	1.90	+284	- 492	-08	+361	-274	+ 82	405000	260329	44
	<i>२185809</i>	8 DE	21550876	657921	3-4704 (MAR 71803 (APR) 261414 (MAY	5823	879	7472	57/3	224	7015	11536	1103	JA467	+310	1	+312	+558	-434	+174	+868	-43).	+436	1404000	NIL	NIL
A - Company of the state of the	248004l	98 WE	T 2786945	3796513	1509170 (MAR. 46A306 (APR 1316451 (MAY. 506586(JUN	6301	1159	8730	5513	400	6991	118/4	1559	15221	+ 199	-6Z	+137	-655	-759	-1414	-456	-821	-1277	6/6500	3180013	530
ì	11/6/40	,	7/550876	6/6/02	MAY	5532		7263	5055	696	6829	10587	1657	14092	+19	+84	-1-103	-100	+38	-62	-8/	+172	+41	463500	152602	25
+	distinct strategapheric screptus agreyaggi		7786945	2 1213473	1150180 (MA)	6080		8278	5734	880	7892	12014	7508	16170	22	+201	+185	-234	279	-5/3	-256	- 72	-328	832500	380973	63
1	734065,	DEI	21550876	923464	280277(BET) 269666(NOV. 3735-26(DFO	5520	774	7064	5782	399	7259	11302	1173	14323	- + 7	-103	-96	+627	-259	+368	+ 634	-362	+272	. 00	925469	154
d.	57 5568	5 WE	r 278694s	2 1466896	MAY	6923	1011.	8704	5577	945	7600	12500	1956	16304	+ 821	-210	+611	-591	214	- Boss	+230	-424	-194	274-1500	NIL	NIL-

TABLE 4.15 RESULTS FOR SIMULATION RUN NO III

رويد مدين مدين نايد مطوري و		ت ت	ा ^र केवा ' सा ' व्यवस्थात । , ' नाम संस्थित ज्ञान स्थान		Manufacture - Proposition and Published State - Proposition - Propositio			POWER	S GE	NERA	TED	estantino con a reposi			*-	—su	RPLUS	(H) ()	R DE	FICIT	(-)	e na sospojeme mladovih atgrisavem	HANGE THE THE PERSON ASSESSED.			79
	OW	0000E	RRIGATION DEMAND	IRRIGATION JULY TO			WER CHARIF			ER II			OTAL		1	LUSORI		TSURP	LUSOR	DEFICI	T SURP	LUSOR	DEFICIT	ACRE FT. WATER	AFTER USING SURP.	ADE
	4 de 1	STA STA	ACRE FT.	AMOUNT IN	DETAILS	BHAKRA	ì	TOTAL	BHAKRA DEHAR	PONG	TOTAL	BHAKE		ТОТА		PONG		BHAKRA DE HAR	PONG	ТОТА	L BHAKR	A PONG	TOTAL	STORED BY SURLU	(ACRE FT.)	1. ZET 1.
. 2	-11.	3	The second second is referred to the second	5	6	7	8	9	10		12	13	14	15	16	17	18	19	20	21	22	23	24	25		Section 2 d 1 Taking 1 Shape 1 Pro
34178	1231	wet	27869452	NIL	NIL	6566	1202	8538	6156	1492	8720	6 1272	2 2694	17264		-		* CHINA 1023-0000 01-1400		a specialist and		and the minimum of management	Property and Management of the Park	2002500	NIL NIL	NIL NIL
25 (4)	6895	AVRG	₹7 86 5452	773271	MAY :	6631	1271	8672	6038	878	7994	12669	2149	16668	+529	+ 50	+579	-130	-281	-411	+399	-231	+168	2605500	NIL	NIL
~ 4 6 8 S	Seros	AVRG	27869452	16154-24	49631 (MAR.) 1773481(APR.) 1039675(MHY) 348770(TUNE)	 	 		6148	-	 	 	-	-	+		-				ļ	ļ			814424	136
of the state	9:541		27869452	NIL	NIL	6488	1127	8385	6382	1312	8772	12870	2439	17157	+386	-44	+292	+214	+153	+367	+600	+59	+659	1314000	NIL	NIL
1753	1518	Dry	16757756	NIL	NIL	5415	743	6928	4112	341	5531	9527	1084	12459	+443	+170	+613	-309	+163	-146	-+134	+333	+467	2758 500	MIL	7-076
24/3	35301	Wet	27869452	1615632	1573886 MAY) 241746 (JUNE)	6934	988,	8692	5300	1053	7431	12234	7041	16123	+832	-233	+599	-868	-106	-974	-36	-334	-375	2695500	NIL	207.
77	1157	Wit	278 6 9452	511751	MAY	6179	1234	8183	6464	867	8409	12643	2101	16542	+ 77	+13	+90	+296	-292	+4	+373	-279	194	405000	10675)	\$ 3
21858	80):	Dep.	215508/6	NIL.	NIL	5623	879	7472	5744	271	7043	11567	1100	14515	+310	+2	+3/2	+589	-437	+152	+899	-435	+464	1464000	NIL	NO.
24 mc	83 Au	Wet	27869452	3684727	1397383 (MAR) 464307 (APR.) 131645 (MAY) 506586 (JUNE)	6350	1159	8279	5520	429	7027	11870	1588	15306	+248	- 62	+186	-648	-730	-1378	400	792	-1192	8370 00	2847.227	4.75
سه خطال المفادسة عن مراه بيناها في رسد	and the state of t	Lip	2100016		建筑水线流。1997年	建设和公司	1	and to	ī		l	1	į i		1			. [•	٠ .	- 1		†	463500	N'L	ج
The second	3(1)20	Wit	27869452	779970	666673 (MAY) 113297 (JUNE)	6364	1338	8477	6019	989	8086	17388	2327	16563	+267	117	1384	-149	-170	-319	+118	- 53	+65	172800c	N/i	No.
3 - 400	6570g	Dep.	21550876	N/L	NIL	5570	8 30	7120	5775	333	7186	11295	1163	14306	+7	-47	-40	620	-325	+795	+627	· -372	+255	NIL	NIL	NIL
√5/5	5685	Wet	4186945 2	1504739	MAY	6809	1025	8604	5522	909	7509	/ <331	1934	16113	+707_	196	5)1 -	-646	-250 -	896	+61	446	- 385	2299500	N	NIL

TABLE 1.16 RESULTS FOR SIMULATION RUN NO IV

7	OTAL NFL OW		DEMAND	IRRIGATION JULY TO	1.	POWE	R IN		POWER	I KHA	RIF		TAL			US ORT		1	USOR C		t	HOLE Y	EAR	THAT CAN BE	AFTER USING	POWER REQU
a de la companya de l	ACRE	Charles Brown	ACRE FT.	AMOUNT IN		BHAKRA. DEMAR	PON6	1 ' 1	BHAKRA. DEHAR	PONG	TOTAL	BHAK RA	PONG	TOTAL	BHAKRA. DE HAR	ì	TOTAL	DEHAR	PONG	TOTAL	BHAKR A DEHAR	PONG	TOTAL	ENERGY IN KHARIF	(ACRE FT.)	
	2	3			6	7	8	9	10	II	12	13	14	15	16	17	18	19	20	21	55	23	24	25	26	27
3	0778231	WET	27869452	NIL	NIL	6566	1202	8538	6156	1493	8727	27/22	2695	17205	+464	-19	+445	-12	+334	+322	+452	+315	+767	2002500	NIL .	NIL
and the state of t	251088 95	AV/ss.	27869452	773271	MAY	6632	1271	8673	6038	878	7994	12670	2149	16667	+ 5 30	+ 50	+580	-130	-281	-411	+400	_231	+ 169	- 26 10000	NIL	NIL
	26 83 8606	AVRG	27869452	1615424	49631 (MAR) 1773986 (APR) 1039675 (MAY) 348720 (JUNE)		1238	8271	6146	7 68	7994	12411	2006	16265	+161	+17	+178	-20	-391	-411	+141	-374	_233	801000	814422	136
1	29491541	WET	2786945	NIL	NIL	6377	1127	8274	4382	1315	8772	12759	2439	17046	+275	-94	+184	+214	4-153	+367	+489	+57	+548	8 1 4 5 00	NIL	NIL.
5	17697518	DRY	16757756	NIL	NAL	5415	7.43	6928	4501	341	5920	9916	1084	12248	+443	+170	+613	1 + 80	1163	+243	+523	+333	+856	2758500	NIL	NIL
	24735361	WET	27869452	2169624	3037-9 (APK.) 1624-15-1 (MAY) 241744(JUN)	7098	1013	8881	5 2 3 3	889	7200	12331	1902	16084	+996	-208	+758	-935	-270	-1205	61	_ 478	-417	3546000	NIL	NIL
7	27359591	WET	2 78 6 9 4 5 2	51(75)	MAY	6179	1234	A-183	6464	8 47	8409	12643	2101	16592	+7.7	+ 13	+ 90	+296	-292	+ 4	+373	-27.9	4.94	405000	106751	18
8	21858098	DEF	21550876	NIL »	NIL	5 8 2 3	879	7472	5744	221	7043	14-567	1100	14515	- 1 -3 j o	ナユ	+312	+589	-437	+152	+899	- 4 37	+464	1404000	NIL	NIL
9	2480048	WET	27869452	3684723	1397382 (man) 464307 (APR 1316447 (MAY) 508686 (Juni	63 5Q	1159	8 279	5520	430	7028	II8TO	1589	15307	+248	62	+186	-648	-729	-1377	- 400	-791	-1191	837000	2847723	475
0	217810-26	DEF	2 15 508 76	Ni	NIL	Man Ask		7263	5011	0.96	6785	10543	1657	14 0 48	+ 19	+ 54	-[- 153	-144	+ 38	-104	-125	+120	-3	4 63500	NIC	NIL
	27003028	WE	T 2786945	2 779970	666673 (MAY) 113297 (JUNE)		1338	8470	6010	78.5	2 8086	12367	2.827	1 6 5 62	+266	* 1.7	4 183	149	-17C	-314	+177	- 53	+ 54	17 23 50 0	NIL	NIL
2	23 406578	DEF	215.5087	6 NIL	NIL	5 5 20	830	7120	5775	333	7186	11295	1163	14306	+7	-47	_45	+620	325	4295	+62*	374	+2.65	NIL	NIC	NIL
3	2575568	r WE	T W66945	1504739	MAY	6809	1025	8604	5522	2 909	7509	12331	1934	16113	+707	-196	+54		2 s o	-896	761	-446		2299500	NIL	NIL

5. SUMMARY AND CONCLUSIONS

5.1. Summary

Water resources systems are generally large and complex. They consist of multiple units and serve multiple purposes. The multiple purposes are not wholly complementary. Several general or problem specific simulation models and computer programmes have been developed for analysing water resources systems SIMYLD II is a computer programme developed by Texas Water Development Board for simulating the hydrologic operation of a system of interconnected reservoirs within a basin or a multibasin water resources system. The study consists in implementing the SIMYLD II programme, validating it with available data and adapting it for the operation of Bhakra Beas system.

The original SIMYLD II programme was implemented in IBM 7044-1401 system at I.I.T. Kanpur and was adapted to meet the requirements of Bhakra Beas system.

Using 13 years of historical data, the Bhakra
Beas system was simulated using the modified SIMYLD II
model. The criteria for defining wet, average and dry years,
the rule curves for operation in wet, average and dry years
and the relative weightages for meeting different demands
and for maintaining the rule curves are derived from simulation analysis. Results indicate that by using these

criteria the benefit from the operation of the system can be greatly increased. Further improvement of the model is also possible.

5.2. Conclusions

The following conclusions emerge from the study:

- i) The original SIMYLD II programme can be implemented in IBM 7044-1401 system with minor modifications due to computer system and by limiting the dimensions of the problem to consider 13 nodes, 20 links and 13 years of monthly data.
- ii) The programme needed additions and alterations
- a) because of difference in the water year b) because of gravity canal rather than pumped canal c) because of differing climate and the corresponding need for defining the state of the system to suit the climate and d) incorporation of energy developed from the system.
- iii) Simulation of Bhakra Beas system indicates that it is possible to derive improved rule curves for the operation of the system in wet, average and dry years and the corresponding priorities between demands and maintaining the rule curves.
- iv) Differing rule curves for wet, average and dry years incorporate the utility of carry over from wet years to dry years.

- v) When a large number of computer programmes are available for simulation of water resources systems, it may be easier to adapt an existing programme than to write a new programme.
- vi) Further modifications for optimization of the system and short term planning are possible.
- 5.3 Suggestions for Future Study
- i) The present study is limited to the consideration of simulation of 13 years operation of Bhakra Beas system. Study of a longer period incorporating heuristic criteria to avoid diversion through Pong when diversion through Dehar is possible, and conjunctive integrated operation of the surface water-ground water system and with the additional details, will lead to better operation of the system.
- ii) Simulation analysis using generated data for stream flow and irrigation and energy requirements, as part of a more comprehensive system planning study is also needed.

LIST OF REFERENCES

- Bhakra and Beas Design Organization, <u>Integrated Water</u> and Power Studies for Ravi, Beas and Sutle; Rivers,

 New Delhi, Aug., 1964.
- 2. Bhakra Beas Management Board, Background Note, Symposium on "Hydrology of Flow Control with Special Reference to Sutlej and Beas Rivers", Nangal, 1976.
- 3. Bhalla, B.S., and Bansal, R.N., "Additional Firm Power without Cost by Judicious Operation of Reservoirs of Interconnected System", <u>Irrigation and Power</u>, Vol.32, No.1, Jan., 1975, pp. 15-19.
 - 4. Cole, J.A., "Control Rules for Multiple Use Reservoirs and Multireservoir Systems", Systems Analysis of Hydrologic Problems, Proc. 2nd Intl. Seminar for Hydrolography. Prof., Logan, Utah, 1974, pp. 343-378.
 - 5. Ford, L.R., J.R., and Fulkerson, D.R., Flows in Networks, Princeton University Press, 1962.
 - 6. Hall, W.A., and Dracup, J.A., <u>Water Resources Engineering</u>, McGraw Hill Book Company, New York, N.Y., 1970.
 - 7. Harbans Singh, "Firming up of Hydro Power by Tubewells and Apportionment of Costs- General Principles and Their Application to Bhakra Power System," Irrigation and Power, Vol.21, No.3, Jul., 1964, pp. 471-480.

- . Hufschmidt, M.M. and Fiering, M.B., <u>Simulation Techniques</u> for <u>Design of Water Resource Systems</u>, Harvard University Press, Cambridge, 1966.
- 9. Hydrologic Engineering Center, Simulation of Flood

 Control and Conservation Systems, HCC-5C, Users Manual
 U.S. Army Corps of Engineers, Davis, CA, 1974.
- 10. Lamba, S.S., and Prem, K.S., "Integrated Development of Rivers Sutlej, Beas and Ravi for Optimum Utility of Water in North-Western Areas of India", Proc. of IWRA Second World Congress on Water Resources, New Delhi, India, Reprint Vol.III, Dec., 1975, pp. 79-87.
 - ll. Iucia et.al., <u>Systems Analysis in Water Resources Planning</u>,
 Rept. No. PB 204374, NTIS, springfield, Va, 1971.
 - 12. Maass, Arthur, et.al., <u>Design of Water Resource Systems</u>.

 Harvard University Press, Cambridge, Massachusetts, 1962.
 - 13. Mehndiratta, K.R., and Hoon, R.N., "Evaporation

 Losses from the Bhakra Reservoir and Reservoir Effect

 on the Local Climatic Conditions" <u>Irrigation and Power</u>,

 Vol.30, No.3, July, 1973, pp. 227-236.
 - 14. Mehndiratta, K.R., and Hoon, R.N., "Regulation of Supplies from the Bhakra Reservoir". <u>Irrigation and Power</u>, Vol.30, No.4, Oct., 1973 a, p.p. 349-356.
 - 15. Ramaseshan, S., "Water Resources Systems Planning and Simulation Techniques", Notes of Lectures, Refresher Course on Systems Engineering, Central Water Commission, New Delhi, 1978.

- 6. Rao, P.S., "Multiobjective Analysis of Punjab Water Resources System," Ph.D. Thesis, Indian Institute of Technology, Kanpur, India, 1976.
- 27. Texas Water Development Board, Economic Optimization

 and Simulation Techniques for Management of Regional

 Water Resource Systems, River Basin Simulation Model

 SIMYLD-II Program Description, Austin, Texas, July, 1972.
- 18. Texas Water Development Board, Stochastic Optimization and Simulation Techniques, Report 131, Austin, Texas, Mar., 1972a.
- 19. Texas Water Development Board, Economic Optimization and Simulation Techniques for Management of Regional Water Resource Systems, Report 179, Austin, Texas, Feb., 1974.
 - 20. Texas Water Development Board, Analytical Techniques for Planning Complex Water Resource Systems, Report 183, Austin, Texas, Apr., 1974a.
 - 21. United States Water Resources Council, Water and

 Related Land Resources: Establishment of Principles and

 Standards for Planning, U.S. Federal Register, 38.174,

 10 Sept., 1973, pp.24778-24869.
 - 22. Wiener, A., The Role of Water in Development, McGraw Hill, 1972.